The impact of developmental dyslexia on workplace cognition: Evidence from a virtual reality environment

Dyslexia and workplace cognition

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The cognitive difficulties associated with dyslexia persist into adulthood but insights into their impact in employment settings are lacking. A virtual office environment was used to assess two areas of cognition frequently called upon in the workplace, executive function and prospective memory. Eight adults with dyslexia and 27 adults without dyslexia were tested on a virtual office task. They read a scenario describing their new role in an office and were given tasks to complete. The group with dyslexia performed worse overall. On the individual performance measures, the group with dyslexia scored lower on the selective-thinking and planning measures of executive function and also performed worse on two of the three prospective memory measures, namely event-based and time-based prospective memory. The findings indicate how dyslexia can affect workplace cognition, identifying areas in which support might be needed and highlighting areas of relative strength which might be harnessed.

CCS CONCEPTS • Applied computing ~Law, social and behavioral science ~Psychology • Social and professional topics ~User characteristics ~People with disabilities

Additional Keywords and Phrases: Developmental Dyslexia; Executive function, Prospective memory, Virtual reality, Workplace cognition

1 Introduction

Neurodiversity refers to all specific learning difficulties, such as attention deficit hyperactivity disorder, developmental coordination disorder, and developmental dyslexia. The need for recognition of neurodiversity in the workplace has been growing recently (e.g., [[1](#bib1)]). The focus of the current paper is on the effects of developmental dyslexia on workplace cognition. Dyslexia is characterized as a specific impairment affecting phonological processing (e.g., [[2](#bib2)]) but broader cognitive problems have also been found and persist into adulthood (e.g., [[3](#bib3), [4](#bib4)]). There is a small research literature on the impact of dyslexia in the workplace (e.g., [[5](#bib5), [6](#bib6), [7](#bib7)]), but much less research that takes a specifically cognitive perspective. In the current paper, a virtual office environment was used to explore two areas of workplace cognition, EF and prospective memory (PM), in dyslexia.

Executive function reflects a set of higher-order cognitive abilities that enable goal-oriented behaviors [[8](#bib8)]. The cognitive mechanisms involved in goal success are inhibiting inappropriate behaviors (inhibition), switching attentional focus based on internal or external demands (task-switching), and concurrently processing and remembering information to enable rule maintenance and task focus (working memory) [[9](#bib9)]. There is some evidence for the impact of EF deficits in the workplace [[10](#bib10)]. Problems with EF are well documented in adults with dyslexia (e.g., [[3](#bib3), [11](#bib11)]).

The PM system is responsible for remembering delayed intentions [[12](#bib12)]. In event-based PM (EBPM), objects in the individual’s surrounding environment act as cues to support PM [[13](#bib13)]. Time-based PM (TBPM) requires an intention to be acted upon at or by a particular future timepoint and relies on internally-generated cues to support remembering [[13](#bib13)]. Like EBPM, action-based PM (ABPM) intentions are environmentally cued and require an intention to be carried out after another task has been performed (e.g., [[14](#bib14)]). Action-based PM is the least cognitively demanding, as the external cues associated with it coincide with the completion of the ongoing activity itself [[14](#bib14), [15](#bib15)], while TBPM is the most cognitively complex (e.g., [[16](#bib16)]). The uses of PM in the workplace are manifold (e.g., remembering to carry out tasks, attach documents to emails, attend meetings, pass on messages to colleagues, coping with interruptions, and monitoring for rarely occurring events over extended durations). The importance of PM in a range of employment settings has been highlighted (e.g., [[17](#bib17)]. Adults with dyslexia have PM difficulties, being greatest for TBPM and with EBPM tending to be less affected [[18](#bib18)].

While evidence exists of the continued impact of dyslexia on cognition in adulthood and of its everyday effects, it is clear that a specific understanding of its effects in employment settings is lacking. The aim of the current study was to obtain a more direct assessment of the effects of dyslexia on workplace EF and PM. To this end, the Jansari assessment of Executive Function (JEF©) [[19](#bib19)] was used to provide a novel and ecologically valid assessment of EF in adults. The JEF© uses a computer-based, non-immersive virtual reality environment to assess cognitive abilities across eight constructs; namely planning, prioritization, selection, creative-thinking, adaptive-thinking, ABPM, EBPM, and TBPM. Resembling a computer game, the participants roleplay working in an office on their first day in a new job. The experimenter reads out loud a list of instructions to the participant from a prepared script, making them aware of the rules and procedures required of them. Typical tasks required in an office environment were selected. Participants navigate around the VR environment using a standard laptop keypad, interacting with objects by clicking them with the computer mouse. Executive function is assessed by performance on tasks designed to measure planning, prioritisation, selection, adaptive-thinking, creative-thinking and multi-tasking. Prospective memory is assessed using tasks that measure ABPM, EBPM, and TBPM.

It was hypothesized that the group with dyslexia would score lower overall on the JEF© [[19](#bib19)]. It was also predicted that the dyslexia group would score lower on the planning measure. Dyslexia-related planning deficits have been reported in adults in educational contexts [e.g., 20] but this ability is under-explored in adults with dyslexia in the workplace. Due to the role of EF in prioritization and selective thinking (e.g., [[21](#bib21)]), it was expected that the adults with dyslexia would perform worse on these measures. Anecdotally, people with dyslexia have been argued to be high in creativity. It remained to be seen whether this would translate to better performance by the group with dyslexia on the creative-thinking measure. Given the evidence for dyslexia-related difficulties in adapting to novel demands [[4](#bib4)], it was predicted that the group with dyslexia would score lower on adaptive-thinking. Dyslexia-related deficits were also expected to be found on the PM measures, with differences being more pronounced for TBPM (see [[18](#bib18)]). Action-based PM has not previously been explored in dyslexia but as it is less cognitively taxing than EBPM [[14](#bib14), [15](#bib15)] and, given the absence of dyslexia-related EBPM deficits over shorter delay intervals [[18](#bib18)], a reduced impact of dyslexia on performance was expected.

2 METHOD

2.1 Participants

Thirty-five adults (27 females, eight males, mean age = 24 years, *SD* = 5.63) were allocated to one of two groups based on their self-declared dyslexia status. The group with dyslexia consisted of eight participants (five females, three males, mean age = 25 years, *SD* = 5.84). There were 27 participants in the group without dyslexia (24 females, 3 males, mean age = 24 years, *SD* = 5.66). There was no significant group difference in age, *t*(36) < 1, *p* = .670. The participants in the group with dyslexia showed the experimenter educational psychologists’ reports to confirm their diagnosis. The group with dyslexia scored significantly lower on both the Nonsense Word Reading Passage (NWR; [[22](#bib22)]) and the spelling component of the Wechsler Objective Reading Dimensions (WORD; [[23](#bib23)]) (*p* = .033 and < .001, Cohen’s *d* = 1.22 and 1.54 respectively).

2.2 Materials

The JEF© [[19](#bib19)] is a virtual reality assessment wherein the participant assumes the role of an office assistant on their first day in a new job. Performance is assessed via tasks related to the eight cognitive constructs identified in the Introduction. Each task is assessed using a three-level scoring system (0 = task not completed; 1 = partially completed; 2 = task completed).

2.3 Design

A multivariate analysis of variance (MANOVA) tested for group differences in JEF© performance. The between-subjects factor was participant group (levels: group with dyslexia, group without dyslexia). The dependent variables were the eight JEF© measures previously identified. To explore the relationship between dyslexia symptomatology and JEF© performance, Pearson’s correlations were run on the reading and spelling scores of all the participants and JEF© scores.

2.4 Procedure

Ethical approval was obtained. Testing was divided between two sessions, occurring on different days. In the first, the reading and spelling measures were administered. In the second, the participants were presented with the virtual office task. The participants read a scenario describing their new role in an office and were shown how to navigate the office virtual environment. They were then given a task list and were told that their manager was not in the office that day. The participants were given a number of “To Do” items throughout the assessment which created further tasks or events, similar to those that would usually occur in an office environment. The participants were debriefed after the second testing session.

3 RESULTS

The descriptive statistics for each of the individual JEF© measures are shown in [Table 1.](#tb1)

Table 1: Descriptive statistics for each of the individual JEF© measures

| Measure name | Mean (*SD*) of the group with dyslexia |  | Mean (*SD*) of the group without dyslexia |  |
| --- | --- | --- | --- | --- |
| Planning | 39.58 (8.63) |  | 77.15 (18.57) |  |
| Prioritisation | 81.25 (17.68) |  | 86.11 (16.01) |  |
| Selective-thinking | 81.25 (22.16) |  | 96.30 (9.05) |  |
| Creative-thinking | 43.75 (39.53) |  | 33.33 (36.69) |  |
| Adaptive-thinking | 81.25 (17.68) |  | 83.33 (21.93) |  |
| Action-based PM | 68.75 (29.12) |  | 77.78 (25.32) |  |
| Event-based PM | 68.75 (29.12) |  | 91.67 (15.50) |  |
| Time-based PM | 71.88 (20.86) |  | 90.74 (12.30) |  |

There was a highly significant multivariate effect of participant group on JEF© performance, Wilks' Λ = .379, *F*(8, 26) = 5.34, *p* = .001, ηp2 = .621. The univariate F-test results are shown in [Table 2](#tb2). The group with dyslexia performed significantly worse on two EF measures (planning and selective-thinking) and two PM measures (EBPM and TBPM).

Table 2: Univariate *F*-test results for the individual JEF© measures

| Measure name | *F*(1, 33) | *p* | ηp2 |
| --- | --- | --- | --- |
| Planning | 30.28 | < .001 | .479 |
| Prioritisation | < 1 | .466 | .016 |
| Selective-thinking | 8.28 | .007 | .201 |
| Creative-thinking | < 1 | .493 | .014 |
| Adaptive-thinking | < 1 | .808 | .002 |
| Action-based PM | < 1 | .398 | .022 |
| Event-based PM | 8.78 | .006 | .210 |
| Time-based PM | 10.38 | .003 | .239 |

The Pearson’s correlation matrix is shown in [Table 3](#tb3). Spelling ability, as measured by the WORD spelling component, was significantly correlated with scores on the JEF© planning, EBPM, and TBPM measures. Reading ability, assessed by the NWR, had significant associations with the JEF© prioritisation, EBPM, and TBPM scores.

Table 3: Correlations between the reading and spelling measures and the JEF© measures

| Measure | WORD | NWR | Planning | Prioritisation | Selective | Creativity | Adaptiveness | ABPM | EBPM | TBPM |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| WORD spelling | - |  |  |  |  |  |  |  |  |  |
| NWR | .811\*\*\* | - |  |  |  |  |  |  |  |  |
| Planning | .533\*\* | .403 | - |  |  |  |  |  |  |  |
| Prioritisation | .163 | .516\* | .013 | - |  |  |  |  |  |  |
| Selective-think | .285 | -.205 | .227 | .158 | - |  |  |  |  |  |
| Creativity | .623 | .049 | -.253 | .214 | .079 | - |  |  |  |  |
| Adaptiveness | .428 | .289 | -.058 | .358\* | .256 | .031 | - |  |  |  |
| ABPM | .037 | .310 | .221 | .156 | -.134 | -.256 | .193 | - |  |  |
| EBPM | .593\*\*\* | .528\* | .302 | .138 | .457\*\* | -.160 | .331 | .183 | - |  |
| TBPM | .504\*\* | .517\* | .263 | .454\*\* | .592\*\*\* | .125 | .482\*\* | .023 | .561\*\*\* | - |

Key: \* = *p* < .05, \*\* = *p* < .01, \*\*\* = *p* < .001

4 DISCUSSION

The participants with dyslexia performed at a lower level overall than the participants without dyslexia on the virtual reality JEF© [[19](#bib19)], indicating deficits in the application of EF and PM to work-related tasks. Group differences were found on two of the EF measures, namely planning and selective-thinking, with the group with dyslexia performing worse than the group without dyslexia on both the measures. The planning measure assesses the ability of the participant to order events or objects on the basis of logic (and not relative importance). This is in line with research findings related to dyslexia-related planning problems in adulthood [[20](#bib20)]. Selective-thinking refers to the ability to draw on acquired knowledge to choose between two or more alternatives. Controlled access to information from long-term memory has been shown to be impaired in people with dyslexia (e.g., [[24](#bib24)]). Given that selective thinking requires rapid access to existing information, this finding adds to the small amount of research in this area and shows a way in which such difficulties might affect everyday cognition. Workers with dyslexia need to be aware of potential difficulties with planning and selective thinking and discuss with employers methods of support (e.g., alternative strategies or software applications). The group with dyslexia also performed worse on two of the three PM measures compared with the non-dyslexic group, with deficits being shown on both the EBPM and TBPM measures. In line with previous findings [[18](#bib18)], the effect size was slightly larger for TBPM than for EBPM. Time-based PM is considered to be more executive-loaded (e.g., [[25](#bib25), [26](#bib26)]) and, thus, likely to be more prone to the effects of the condition (see [[18](#bib18)]). No group difference was found on the ABPM measure. As stated in the Introduction, this form of PM is both the least complex and the most environmentally-supported [[14](#bib14), [15](#bib15)]. These task qualities may explain the absence of a group difference. Areas of relative strength in PM could be utilized to improve performance to a level at least equivalent of that of adults without dyslexia [[18](#bib18)]. Based on the current data, workers with dyslexia should aim to change the nature of their work-based PM tasks so that they rely on action-based cues. As further support for the relationship between dyslexia symptomatology and aspects of work-based cognition, significant positive correlations were found between scores on the reading and spelling measures and several JEF© measures. In the case of the EF measures, planning was correlated with spelling ability and prioritization with reading ability. A more consistent pattern was found with the PM measures, with both reading and spelling ability being associated with EBPM and TBPM, but not ABPM.

There are several limitations to the current study. The participants were university students rather than office workers. Further work is needed to examine any mitigating role that office experiences might play in the performance of workers with dyslexia. The number of participants in the group with dyslexia was small but, where significant group differences were found, the effect sizes were relatively large. It should also be noted that no measure of IQ was administered but the findings are consistent with previous work where measures of IQ were taken [[18](#bib18)].

This virtual reality study has allowed the direct study of workplace cognition in adults with dyslexia, indicating areas of weakness and relative strength in EF and PM abilities that are relevant to office settings. The knowledge gained from this study can help in providing targeted support for employees with dyslexia in areas of workplace cognition beyond those drawing on literacy-related skills. The results also highlight the value of virtual reality methodologies in testing office-based cognition, allowing insights into the ways in which neurodiversity can be expressed in the workplace and emphasizing the need for appropriate support to be in place to help all individuals achieve their full potential at work.

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