Dyslexia and hand preference in secondary school students

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Abstract
Research results with regard to handedness and dyslexia have been ambiguous. The present study investigated the relationship between handedness and dyslexia in secondary school students based on genetic (Right-Shift) and hormonal-developmental theories of handedness. A total of 135 students (45 dyslexics and 70 age- and sex-matched controls) participated in the study. Handedness was defined according to the Edinburgh Handedness Inventory. We developed several classifications that represented various levels of handedness. Both continuous and dichotomous classifications of handedness revealed a small but reliable increase in the proportion of non-right-handers among dyslexics, likely because of the increased proportion of dyslexics among pure left-handers. Dyslexics did not display precisely the same pattern of right and left responses as controls, with some differences at the extremes of the continuum. The present results provide empirical support for Annett’s (1985) Right-Shift theory predictions. Additionally, the present study indicates that using a numerical scoring system or dichotomous classifications with restricted criteria that permit the measurement of several degrees of handedness appears to better determine hand preference than using broad classifications into handedness groups.

Keywords: dyslexia, hand preference, secondary school students.

Introduction
Dyslexia is the most common and carefully studied learning disability in school-age children (Shaywitz, Fletcher, & Shaywitz, 1995). It is characterized by marked impairment in the development of reading skills and affects a large number of persons (Shastry, 2007). Orton (1928) attempted to explain the genesis of reading disabilities by proposing a putative link between hand preference and developmental problems. The belief was that these deficits were somehow associated with atypical cerebral organization reflected by non-normal patterns of handedness. The link between left-handedness and dyslexia was boldly stated by Geschwind & Behan (1982) who found an elevated incidence of self-reported dyslexia and stuttering, tabulated separately, in a large sample of strong left-handers. They reported that very strong left-handers were 11 times more likely to have dyslexia than very strong right-handers. Such findings led Geschwind & Galaburda (1987) to propose their hormonal-developmental theory, postulating that a fundamental link exists between abnormal development of the left hemisphere, reduced dextrality, various learning disorders, immune disorders, and other medical conditions, forged by the prenatal influence of fetal testosterone on the developing nervous system.

Other studies of dyslexics found the predicted excess of non-right-handers and that some dyslexics were strongly biased toward the right for hand skill (Annett & Kilshaw, 1984). Annett & Manning (1990) found an excess of poor readers at both the left and right of the hand skill continuum in a general school sample. These findings were consistent with the Right-Shift theory of Annett (1985), which suggested that the increase in mixed and left handers among dyslexics is attributable to the fact that some people with specific language problems lack the rs+ gene, which gives most people a left hemisphere advantage for speech and shifts the handedness distribution toward dextrality. According to Annett (1985), poor readers with poor phonology should be unbiased toward either side for hand skill. There should be more left handers and also more mixed handers as expected for a random distribution of handedness, without any shift to the right. The Right-Shift theory also predicts that there should be some poor readers who do not have problems with phonological processing but have other difficulties, probably with visual memory functions. The prediction was that the latter would be strongly biased toward dextrality as expected for the rs+ genotype.

Bishop (1990) reviewed 25 studies on handedness with regard to developmental disorders such as dyslexia and specific language impairment that met stringent methodological criteria and concluded that such an
association had little support. Bishop (1990) stated that the results of Geschwind & Behan (1982) were “totally discrepant with those reported by other workers” (Bishop, 1990, p. 147). She concluded that theories that predict differences in rates of left-handedness or the relative skill of two hands in either dyslexia or specific language impairment have little support. A reanalysis of the same studies using newer meta-analytical procedures (Eglinton & Annett, 1994) showed a small but reliable increase in the proportion of non-right-handers among dyslexics as expected by the Right-Shift theory of handedness of Annett (1985).

A study by Tonnessen, Lokken, Hoen, & Lundberg (1993) found relatively weak but supportive evidence that indicated an elevated prevalence of left-handedness in individuals with dyslexia. Another study by Locke & Macaruso (1999) assessed manual laterality in dyslexic students and concluded that although the dyslexics did not show precisely the same pattern of right and left responses as controls, the differences between groups were few and not present at the extremes of the continuum (i.e., neither a significantly lower percentage of pure right-handers nor a higher percentage of pure left-handers was found among the dyslexics).

Based on the aforementioned studies, we can conclude that the research results on handedness and dyslexia are ambiguous at best, indicating a need for further clarification. Koufaki & Papadatou-Pastou (2013) suggested that investigations of the relationship between handedness and reading disability must contend with a lack of consensus over the definition and measurement of handedness and the variability in the definition of dyslexia. According to Brenneman, Decker, Meyers, & Johnson (2008), one of the reasons research on handedness and dyslexia has been ambiguous is that handedness is often measured as a dichotomous variable rather than as a continuous variable, and this methodological difference contributes to the diverse research findings. However, as indicated by Dragovic (2004), the majority of existing handedness questionnaires lack valid criteria for partitioning the continuous measure into a small number of handedness classes. That is the reason why researchers (e.g., Boscaino & Hoffman, 2007; Giotakos, 2001; Taylor, Dalton, Fleminger, & Lishman, 1982) sometimes use more than one criterion to test the stability of their findings or allow comparability with similar studies. To overcome this methodological problem, the present study evaluated the association between lateral preference for handedness and developmental dyslexia using both continuous and several dichotomous classifications of hand preference.

The hypotheses explored in the present study were based on the two aforementioned theories of handedness. More specifically, if the delayed development of the left hemisphere in left-handers, as proposed by Geschwind & Galaburda (1987), is correct, then there should be a significant preponderance of left-handed students among dyslexics (Hypothesis 1). Conversely, according to the expectation of the Right-Shift theory of Annett (1985), we could predict an increase in mixed and left-handers (i.e., non-right-handers) among dyslexics and an increased percentage of strong dextrality in dyslexics compared with controls (Hypothesis 2).

Methods

Participants

A total of 135 secondary school students (102 boys and 33 girls; age range 13-18 years) participated in the study. The dyslexic students (n = 45; age range 13-18 years; M = 15.14 years, SD = 1.46 years) had a statement of dyslexia after assessment at the Centre of Diagnosis, Assessment and Support of Magnesia, Greece. This center belongs to the Ministry of Education and is listed among the formal assessment centers for specific learning difficulties. The assessment was performed by a psychologist and special educator using the following criteria: (a) assessment of intelligence, (b) assessment of cognitive skills (i.e., visual discrimination, visual and auditory short-term memory, spatial orientation, laterality, etc.), and (c) assessment of oral reading accuracy, reading rate, reading comprehension, listening comprehension, dictation, and free writing using informal reading inventories. Students with dyslexia had a consistent history of persistent specific literacy difficulties, with reading levels at least 18 months behind their chronological age but with an Intelligent Quotient >80 on the Greek version of the Wechsler Intelligence Scale for Children—Revised (3rd edition; WISCIII-R). A comparison group (n = 90; age range 13-18 years; M = 15.05 years, SD = 1.49 years) consisted of pupils who attended the same classes as the dyslexics and did not have a history of major medical illness, psychiatric illness, developmental disorder, or significant visual or auditory impairments according to the medical reports of their schools. Participants in the control group were matched for age and gender with the dyslexics. All of the participants had Greek as their first language and attended mainstream public schools.

Measures

Handedness was defined according to the Edinburgh Handedness Inventory (EH1; Oldfield, 1971), a reliable and well-validated instrument (Bryden, 1977). Numerous studies have confirmed the objectivity and reliability of the EHI with other handedness questionnaires (e.g., Dorthe, Blumenthal, Jason, & Lantz, 1995; McMeekan & Lishman, 1975; Ransil & Schachter, 1994; Williams, 1986). The test-retest reliability of the EHI measured by the Pearson r, Kendall τ, and Spearman r, ranged from 0.95 to 0.98 (Ransil & Schachter, 1994). The medium to high correlations of the EHI with the other behavioral measures of handedness (e.g., the Purdue Pegboard test, a test of manual dexterity) underscore the high concurrent validity of the test (Raczkowski, Kalat, & Nebes, 1974; Triggs, Calvano, Levine, Heaton, & Heilman, 2000; Verdino & Dingman, 1998). Additionally, the Citation
Dyslexia and hand preference

Dyslexia and hand preference

The Edinburgh Handedness Inventory (EHI) is a widely used instrument to assess hand preference. The questionnaire consists of 10 items that measure hand preference in writing, drawing, throwing a ball, using scissors, a toothbrush, a knife (without fork), a spoon, and a broom (upper hand), striking a match, and opening a box. A score of 0 were divided as right-handers (EHI score +1 to +100) using Oldfield's (1971) categorization, the students varied as right-handers (EHI score -90 to -100), moderate left-handers (EHI score -50 to -89), and pure left-handers (EHI score -90 to -100). Table 1 summarizes the aforementioned classifications.

Results

The mean EHI scores were 5.87 (SD = 6.81) and 7.10 (SD = 4.78) for the dyslexic and control groups, respectively. A t-test with EHI scores as the dependent variable and group (dyslexics vs. controls) as the independent variable was used. The analysis revealed that the difference in mean EHI scores between the dyslexic and control groups was not statistically significant ($t_{133} = -1.22, p > .05$), indicating that the two groups did not present significant differences in their handedness scores.

Table 1. Three dichotomous handedness classifications of the participants according to their EHI score

<table>
<thead>
<tr>
<th>Classification</th>
<th>Handedness classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right-handers</td>
</tr>
<tr>
<td>1st</td>
<td>+1 to +100</td>
</tr>
<tr>
<td>2nd</td>
<td>+50 to +100</td>
</tr>
<tr>
<td>3rd</td>
<td>+90 to +100</td>
</tr>
</tbody>
</table>

EHI, Edinburgh Handedness Inventory.
that the differences between controls and dyslexics were statistically significant ($\chi^2 = 9.98, df = 4, p < .05$). More specifically, pairwise post hoc comparisons revealed that dyslexics were overrepresented not only in pure left-handers (11.1% in dyslexics vs. 2.2% in controls) but also in pure right-handers (57.8% in dyslexics vs. 47.8% in controls), whereas they were underrepresented in moderate right-handers (20.0% in dyslexics vs. 42.2% in controls).

**Discussion**

Using both continuous and several dichotomous classifications of hand preference in the present study, we investigated the relationship between handedness and dyslexia in Greek secondary school students based on genetic (Right-Shift) and hormonal–developmental theories of handedness.

Our first hypothesis predicted an increased incidence of left-handers among dyslexics based on the hormonal–developmental theory (Geschwind & Galaburda, 1987), which correlated abnormal left-hemisphere development with learning disorders and non-right-handedness. Indeed, the two more broad dichotomous classifications of handedness revealed an elevated proportion of left-handers among dyslexics. This difference was in the direction expected but not statistically significant; therefore, we have to reject our first hypothesis.

The second hypothesis of the present study arose from Annett’s (1985) Right-Shift theory. According to this hypothesis, the prediction was an increase in mixed- and left-handers (i.e., non-right-handers) among dyslexics and an increased percentage of strong dextrality in dyslexics compared with controls. Both

![Figure 1. Percentages of Edinburgh Handedness Inventory (EHI) scores within the dyslexic and control groups.](image)

**Table 2. Percentage of students per handedness classification group within the control and dyslexic groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Right-handers</th>
<th>Moderate right-handers</th>
<th>Mixed-handers</th>
<th>Moderate left-handers</th>
<th>Left-handers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>91.1</td>
<td>8.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyslexic</td>
<td>82.2</td>
<td>17.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>90.0</td>
<td>4.4</td>
<td>4.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyslexic</td>
<td>77.8</td>
<td>4.4</td>
<td>4.4</td>
<td></td>
<td>17.8</td>
</tr>
<tr>
<td>Control</td>
<td>47.8</td>
<td>42.2</td>
<td>4.4</td>
<td>3.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Dyslexic</td>
<td>57.8</td>
<td>20.0</td>
<td>4.4</td>
<td>6.7</td>
<td>11.1</td>
</tr>
</tbody>
</table>
Dyslexia and hand preference

the second and third dichotomous classifications of
dehandedness confirmed this prediction, indicating more
non-right-handers (i.e., left-handers plus moderate
left-handers plus mixed-handers) in dyslexics than in
controls. A careful observation of Table 2 reveals that
overrepresentation of non-right-handers in dyslexics is
mainly attributable to the fact that significantly more
dyslexics (11.1%) were pure left-handers compared
with their matched controls (2.2%). The continuous
measure of handedness verified this finding. Figure
1 shows that the percentage of dyslexic students who
scored -100 (pure left-handers) was higher than controls.
Interestingly, the proportion of dyslexic students who
scored +100 (pure right-handers) was also higher than
controls. This finding was not detectable from the two
more broad dichotomous classifications of handedness
but emerged from both the third dichotomous and
continuous classifications. The surprising idea that strong
right-handers could be at risk for reading difficulties
was first suggested by findings in a dyslexia clinical
sample (Annett & Kilshaw, 1984). The reliability of
this finding was checked in a school sample when mean
reading quotients were found to be lower at both ends
of the laterality distribution (Annett & Manning, 1990).
The present results offer empirical support for Annett’s
(1985) Right-Shift theory predictions, confirming our
second hypothesis.

Our results are also consistent with the results of
the meta-analysis performed by Eglington & Annett
(1994), which found more sinistrals and mixed-
handers throughout the dyslexia population, suggesting
a probable relationship. A very recent meta-analysis
(Koufaki & Papadatou-Pastou, 2013) attempted to
replicate and update the results of Eglington & Annett
(1994). This updated meta-analysis included 44 studies
and confirmed the statistically significant increase in non-
right-handedness among dyslexics compared with non-
dyslexics, providing support for the hypothesis of specific
language-associated brain function that is not adequately
lateralized to the left hemisphere in people with dyslexia.

Our findings are consistent with previous studies
(e.g., Tonnessen et al., 1993) that found a relationship
between hand preference and dyslexia but not
necessarily between left-handedness and dyslexia.
However, our results do not support other studies
(Peters, Reimers, & Manning, 2006), which found that
individuals who indicated “either” hand for writing
preference had a significantly higher prevalence of
dyslexia than individuals who had clear left or right hand
preferences. A possible reason for this discrepancy is
the way handedness was assessed. In the previous study,
although the researchers conducted an internet study with
a very large sample (i.e., >250,000 participants),
they did not use a questionnaire to assess handedness.
The participants answered only a graded question
about which hand they preferred for writing, but this
criterion is not sufficient to distinguish clear hand
preference groups. Peters et al. (2006) concluded that
contradictions in the literature about whether dyslexia or
other behavioral variables are linked to handedness stem
largely from different definitions of hand preference.
According to Eglington & Annett (1994), an additional
reason for the inconclusive findings in the literature
may be attributable to a failure to discriminate dyslexia
subtypes. This assumption was confirmed by a recent
review of findings on dyslexia and handedness (Annett,
2011), which concluded that phonological dyslexics
are less likely to be right-handed, whereas surface or
dyseidetic dyslexics are more likely to be right-handed
compared with the general population.

The fact that we could not discriminate subtypes
of dyslexia in our sample constitutes a limitation of
our study. Another limitation is the small sample size
that led to few mixed- and left-handers. Including more
mixed- and left-handers would necessitate a much larger
sample because the percentage of non-right-handers in
the general population or in dyslexics is small.

Overall, our results indicate that dyslexics did
not display precisely the same pattern of right and left
responses as controls, with some differences at the
extremes of the continuum. More specifically, both
continuous and dichotomous classifications of handedness
revealed a small but reliable increase in the proportion
of non-right-handers among dyslexics, likely because of
the increased proportion of dyslexics among pure left-
handers. Notwithstanding, there appears to be no reason
to treat left-handed children as an at-risk population for
dyslexia because an increased proportion of dyslexics
was observed among pure right-handers as well.

Additionally, the present study indicates that
using a numerical scoring system or dichotomous
classifications with restricted criteria that permit the
measurement of several degrees of handedness appears
to better determine hand preference than using broad
classifications into handedness groups.

In summary, the present results may allow us to
draw a conclusion that is similar to Locke & Macaruso
(1999) who proposed that even if an elevated incidence
of left-handedness or less-strong right-handedness exists
in dyslexics, the typical dyslexic adolescent is strongly
right-handed. This conclusion supports previous research
findings (Natsopoulos, Kiosseoglou, Xeromeritou, &
Alevriadou, 1998) suggesting that left-handers consist
of heterogeneous subgroups of subjects at either extreme
of abilities, with significantly more subjects performing
worse and significantly fewer subjects performing better
than right-handers. The above argument appears to
reinforce theoretical claims (Satz, Orsini, Saslow, & Henry,
1985; Bishop, 1990) about the inclusion of a proportion
of potentially pathological persons among nonclinical
left-handers, even if they do not present overt neuromotor
abnormalities. This may be the reason Gaillard & Satz
(1989) suggested that the association between handedness
and ability depends on whether the cohort is selected from
a general school population or from a clinical population.
In the former case, null results are usually reported. In
contrast, studies based on clinical samples have often
reported a significant effect of handedness.