Causes of Dyslexia in a Dual Intervention Approach

One of the key questions in dyslexia research is what causes dyslexia? In the literature on dyslexia this question is discussed, but these discussions are meaningless unless the notion of causality is not clarified and used in its vague unscientific meaning. It is a fundamental insight that concepts must have a clear meaning in all scientific contexts. To determine whether something is a cause and which methods reveal whether there is a causal relationship, it is not possible to refer to an obscure everyday language concept of cause. Therefore, various proposals have been made to mathematically specify the concept of cause (Mackie 1965; Spohn 1980, 2006; Spirtes et al. 1992; Lewis 2000; Pearl 2003; 2000-2018; Pearl et al. 2016). The present paper proposes a concept of causality that enables us to show whether impaired capacites, such as reduced attention, reduced capacity of simultaneous recognition, or too large saccade amplitudes, are causes of a reading disorder. A simple definition of the concept of cause is given here, which can be applied to the question of what are the causes of dyslexia. Since the question of the cause of dyslexia is answered in a methodological framework that we call the "dual intervention approach", the term "dual intervention approach" is defined first.

Definition 1: dual intervention approach

An experimental approach is a dual intervention approach if and only if

(1) V is a group of experimental subjects who performed the compensatory pseudoword experiment described above to investigate under which conditions the subjects are able to read at least x % of a list of pseudowords correctly.

In the experiments reported in Werth (2018) each subject improved his/her reading performance so that s/he reached a reading score of $x = 95$ % correctly recognized

pseudowords

(a) if the pseudowords did not contain more letters than the subject was able to recognize simultaneously,

(b) if the fixation time was increased to such an extent that the subject was able to recognize a given number of letters simultaneously, and

(c)if the time interval needed to retrieve the phonemes of the words to be read correctly from memory was extended.

(2) The group of subjects is divided in a therapy group and in a control group so that the two groups are as similar as possible according to the results of the compensatory pseudoword experiment.

In the ideal case each group contains the same number of subjects of the same age who have the same ability to read a given number of letters simultaneously within about the same fixation time and who need about the same time to retrieve the phonemes from memory presupposing the words to be read are fixated at the right location.

(3) Based on the results of the compensatory pseudoword experiments, the subjects in the therapy group learn a reading strategy through which they improve their reading performance so that they reach a reading score of h_1 (e. g. few or no reading mistakes).

In the therapy experiments reported in Werth 2018 each subject improved his/her reading performance so that s/he reached a given reading score

(a) by attempting to recognize not more letters simultaneously than s/he was able to,

(b) by adjusting the amplitude of eye movements to the number of letters that s/he could recognize simultaneously,

(c) by increasing the fixation time to such an extent that s/he could recognize a given

number of letters simultaneously, and

(d) by extending the time needed to retrieve the phonemes of the words to be read correctly from memory.

(4) The control group learns no new reading strategy. Both groups read the same texts for the same amount of time.

(5) The subjects in th teherapy group improve their reading ability to a given effect size g_1 and the subjects in the control group does not improve their reading performance according to a given effect size g_2.

(6) The experimental results are repeatable with different groups of subjects.

Definition 2: cause

Let C* be a set of reading conditions (e. g. number of letters to be read simultaneously, fixation time, time to retrieve phonemes from memory, eye-movement amplitudes) within a dual intervention approach under which reading performance reaches a score h_1 (e. g. few or no reading mistakes), and let h_2 be a score that represents a lower reading performance than h_1 (i. e. a high rate of reading mistakes).

Then the impairment or absence of elements C which are a subset of C* is a **(necessary) cause** for the poor reading performance h_2 if and only if reading performance deteriorates to a reading score h_2 (e. g. rate of reading mistakes),

(i) if all elements of C* except C are present,

(ii) if C is not replaced by a different reading condition D or if the replacement of C leads to a reading performance that is lower than h_1,

(iii) if C does not contain a component K_C so that the reading performance deteriorates to the score h_2 if only K_C is impaired or missing.

E is a (sufficient) cause for the poor reading performance h_2 if and only if
(i) E is a set of reading conditions that are no subset of conditions C*,
(ii) the subjects reach a reading score of h_1 if only the reading conditions C* are present,
(iii) reading performance deteriorates to a reading score h_2 (e. g. rate of reading mistakes) if
conditions C* and conditions E are present.

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