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**Implicit Statistical Learning and Explicit  
Statistical Learning in an Artificial Grammar  
Learning:  
A Comparison between Typically Developing  
and Dyslexic Adults Readers**

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# Abstract

Comprehensive discussion has taken place in research literature over the past few years concerning Developmental Dyslexia (DD), its characteristics, and underlying difficulties. The prevailing hypothesis over the past forty years claims that the main deficiencies of individuals with dyslexia originate in the phonological processing system. This hypothesis has been opposed by more recent findings suggesting that dyslexia may originate from more generalized cognitive difficulties. One cognitive skill that has been found to be related to reading acquisition is statistical learning: the ability to detect statistical regularities in sequential stimuli. There is evidence that readers with dyslexia have deficits in statistical learning processes; this has been found primarily in tasks involving implicit learning processes. These findings have led to the hypothesis that statistical learning deficits will appear in adults with dyslexia during implicit learning tasks, but not during explicit learning tasks.

The aim of the present study is to explore implicit versus explicit statistical learning processes using Artificial Grammar Learning (AGL) tasks, while comparing readers with dyslexia and typically developed (TD) readers. It is important to distinguish between implicit and explicit statistical learning among readers with dyslexia: this distinction enables a better understanding of the difficulties in statistical learning among these readers and may enhance our understanding of implicit statistical learning performance compared to explicit statistical learning performance. The present study also aims to evaluate the learning characteristics of readers with dyslexia, by measuring participants' subjective assessment of information acquired during the artificial

grammar task. This evaluation enables better access to participants' consciousness, exposing their level of awareness of their own acquisition of knowledge.

Recent research has addressed the differences between implicit and explicit statistical learning. In implicit tasks, participants are exposed to training sequences without awareness of the underlying rules of these sequences and with no opportunity to explain what was learned. In explicit tasks, on the other hand, participants are informed prior to the training phase that the training sequences were based on underlying rules. This information is given to participants in order to trigger their awareness of the learning process and allow them to detect the underlying rules in all or part of the task sequences.

Participants' performance during the test phase is measured by the number of correct answers obtained, without reference to the participants' awareness or the information they learned. This count of correct answers comprises an objective measurement. Nevertheless, some researchers claim that this method loses some important information since it does not take into account the participants' motivation and thought processes while classifying the sequences as grammatical or not. They claim that more subjective measures would allow access to participants' awareness during artificial grammar tasks, making participants more aware of what they have learnt while exposed to the sequences of the task. Examination of subjective measures among readers with dyslexia during explicit statistical learning tasks in the audio modality has indeed shown that subjective measurement tools allow access to higher levels of knowledge in explicit statistical learning tasks. However, research has not yet been done on subjective measures among readers with dyslexia during explicit statistical learning tasks in the visual modality, in which the distinction between implicit and explicit statistical

learning tasks is particularly important due to the difficulties that readers with dyslexia experience when performing implicit statistical learning tasks.

Therefore, the current study measures both implicit and explicit statistical learning tasks among adults with dyslexia. It includes objective and subjective methods of assessing the learning processes employed during a visual artificial grammar learning task. The explicitness of the task was implemented using direct instruction to participants to search for rules; a subjective questionnaire was also used to assess the information acquired by participants during the task. Participants were divided into two groups: one group included an implicit visual artificial grammar task without any directive to search for rules, while the other included an explicit visual artificial grammar task and instruction to search for rules within the sequences. Each of these groups was further divided into an experimental and a control group. 32 adults participated in the first group, which included 17 in the control group (TD readers) and 15 in the group of readers with dyslexia. The second group was comprised of 27 adults: 14 in the control group (TD readers), and 13 in the group of readers with dyslexia. Participants' ages ranged from 20 to 35.

The results of the study showed that in the objective measures, readers with dyslexia succeeded in learning statistical regularities during both implicit and explicit tasks. However, there were significant differences in their performance on the two types of tasks: their performance on explicit tasks was significantly higher than their performance on implicit tasks. TD readers, on the other hand, showed no significant performance differences between implicit and explicit tasks. These findings indicate that readers with dyslexia have a deficiency in implicit statistical visual processing. Nevertheless, when instructed to search for rules, readers with dyslexia succeeded

better in identifying the statistical regularities upon which the stimuli were based. These findings support the hypothesis that the central deficit of individuals with DD is in implicit, rather than explicit, visual statistical learning. They also support the theory that the statistical learning mechanism is not only a domain-general mechanism, but rather a mechanism that combines several domain-specific learning processes. This is reflected in differences between implicit and explicit learning, as evidenced among readers with dyslexia.

The subjective measure of information acquired during the task was examined by having each participant attribute their classification for each sequence to one of five different levels of explicit knowledge. The study's findings correlated the responses from the two different task types, yielding an interaction between the research groups. Among typically-developed (TD) readers, no significant differences were found between responses on implicit and explicit tasks; in contrast, adult readers with dyslexia attributed their responses to higher levels of explicit knowledge during the explicit tasks than during the implicit task. These findings support what emerged from the objective measures. They show that readers with dyslexia attribute their classifications during explicit learning tasks to higher levels of explicit knowledge than they do in implicit learning tasks. These findings also demonstrate that an explicit instruction to search for rules during an artificial grammar task enables readers to access greater awareness of these rules. This helps them to increase their awareness to rules, compensate for the difficulty they experience in implicit learning tasks and improve their performances in explicit learning tasks.

Difficulties in implicit learning of underlying regularities during an artificial grammar task, as found in the present study, show that although readers with dyslexia do succeed

in detecting regularities from sequential stimuli, their learning is limited and may reflect a failure to develop automaticity. This failure originates from a difficulty in monitoring attention for focusing and assimilation of rules that underly learning. Still, explicitly increasing awareness of rules for readers with DD can compensate for their difficulties in implicit learning.

The importance of the current study is that it emphasizes the need to distinguish between implicit and explicit learning tasks as they relate to statistical learning among readers with dyslexia, as well as the importance of using subjective measures for such readers. The results of this study substantiate previous findings and confirm knowledge on the difficulties of readers with dyslexia during implicit statistical learning tasks. In addition, they broaden our understanding of the difficulties of readers with dyslexia by providing access to their subjective experience during learning. A general understanding of the difficulties using objective and subjective measures emphasizes the importance of directed learning, which may compensate for the difficulties of readers with dyslexia and assist them in learning processes.