# BAR-ILAN UNIVERSITY

## Examination of Statistical Learning, Implicit and Explicit, via Artificial Grammar Learning Task in Visual and Auditory Modalities:

## Comparison between Poor and Skilled Spellers

Rotem Gilad Patriano

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# Abstract

Spelling is an autonomous and abstract linguistic system, with its own inner categories and regularities. In order to acquire the system of rules and control it, one must be exposed to written words and learn to identify and extract letters and sound sequences that are learned in explicit and implied methods, both visually and audially (Plaza & Cohen, 2006; Richards, Berninger, & Fayol, 2009; Liow & Lau, 2006). In addition, cognitive processes, such as generalization, categorization and the acquisition of spelling rules, are required (Ravid & Berman, 2010; Steffler, 2001; Graham, 2000). Thus, the learner is exposed in his/her environment to the written words via statistical learning processes, activated in both explicit and implicit methods. For example, when a learner is exposed several times to the same words or words of similar structure during the course of reading, he extracts the repeated letter and sound sequences in an implicit method. For example repeated exposure of words ending in 'av' leads to generalization, categorization and the acquisition of spelling regularities, indicating that 'av' implies of a possessive suffix.

Studies examining the development of spelling skills indicate that most of the spelling rules are acquired in implicit learning that is mainly the result of exposure. However, some spelling rules are learned explicitly and openly in school and outside it (Steffler, 2001; Graham, 2000). Despite the clear ability of young students to acquire spelling regularities, many of them are unable to do so, and are referred to as "poor spellers" (Ravid, 2002; Ise, Arnoldi, Bartling, & Schulte-Korne, 2012; Holmes, Malone & Redenbach, 2008).

The professional literature raises several hypotheses regarding the source of difficulties for poor spellers in acquiring spelling rules. According to the first hypothesis (Pavlidou et al., 2009, 2010; Steffler, 2004; Ise et al., 2012), poor spellers have difficulties in acquiring spelling rules due to a difficulty in implicit learning of statistical regularities for verbal stimuli (letter sequences) and non-verbal stimuli (sound sequences). This hypothesis is based on the fact that acquiring a spelling system requires several cognitive abilities, including the statistical learning ability of repeated letter sequences, reflecting spelling rules.

Recent studies dealing with acquisition of the rules of the spelling system indicate a connection between statistical learning and the acquisition of a language and various linguistic skills, such as reading (Arciuli & Simpson, 2013) and writing (Steffler, 2001, 2004; Graham, 2000; Kemper et al., 2012; Ise et al, 2012), while using implicit and explicit learning processes. The few studies examining statistical learning skills among the poor spellers focused on implicit learning processes (Ise et al., 2012; Steffler, 2004), while their explicit learning ability was not yet examined.

Thus far, studies examined the implicit learning ability of statistical regularities in young subjects with disabilities, such as spelling difficulties, compared to typically developed subjects (Pavlidou et al., 2009, 2010; Steffler, 2004; Kemper et al., 2012). A single study, by Ise, (Ise et al., 2012) examined the implicit learning abilities among pure poor spellers (without additional disabilities), however, it did not differentiate between explicit and implicit learning. Therefore, the main goal of the current study was to examine explicit and implicit statistical learning abilities among poor spellers compared to skilled spellers in the $6^{th}$ grade. This examination was conducted in visual and auditory methods.

One of the most common tasks in the study for the examination of statistical learning ability is the Artificial Grammar Learning (AGL) task. This task examines the ability of the subject to identify the regularity of the presented symbol sequences (Reber, 1967; Dienes & Scott, 2005; Dienes & Longuet-Higgins, 2004; Pothos, 2007). This ability is examined both implicitly when the subject is not aware of the task, and explicitly when the subject receives guidance in identifying the regularities from a complex set of stimuli to which he is exposed.

The current study examined the implicit and explicit statistical learning abilities of poor spellers, when exposed to verbal sequential stimuli, in both visual and auditory methods. There are two main approaches referring to the effects of the methods and type of stimuli on statistical learning processes. One approach refers to the statistical learning processes as having a global domain (domain general), i.e, processes aimed at learning the rules that underlie the stimuli, regardless of the type of stimulus presented (Reber, 1993). The other approach claims that the implementation of general learning processes is conducted simultaneously with processes specifically adapted to the modality and type of stimulus presented (domain specific) (Photos, 2007). Frost, Armstrong, Siegelman, & Christiansen (2015) proposed a neurobiological model

combining both approaches. According to this model, the stimulations presented in the AGL task often contain several methods. These stimulations activate different areas of the brain that at times conflict with one another. Thus, implicit learning is the result of the integration of several mechanisms triggered by several methods.

In order to broaden the knowledge on the source of the difficulties of poor spellers in executing statistical learning processes and identifying whether it is a general or specific stimulus (visual or auditory), two experiments were conducted in the current study. The first experiment examined the explicit and implicit statistical learning abilities of poor and skilled spellers in the visual method – letter sequences in English, presented on a computer screen. 40 6$^{th}$ graders participated in the experiment who were not diagnosed with additional learning disabilities, attending state-secular schools in central Israel. Following mapping tests that included three dictations, the subjects were divided into two groups: poor and skilled spellers. First, each subject performed the implicit AGL task, and 30 minutes later, the explicit task. In the second experiment, the explicit and implicit statistical learning abilities of poor and skilled spellers were examined in an auditory method by audible sequences. The process of the second experiment was identical to the first, and included 40 6$^{th}$ graders, divided into two groups following mapping tests.

The results of the study revealed that both study groups surpassed the guessing level in all tasks, indicating that both poor and skilled spellers experienced learning. Nevertheless, poor spellers exhibited a lower statistical learning ability compared to skilled spellers, in both visual and auditory AGL tasks. No significant differences were found between the performance of the poor and skilled spellers in the examination of the explicit task. Moreover, skilled spellers exhibited lower achievements in the explicit task compared to the implicit task. The findings of the study support the hypothesis that the ability to learn the identification of statistical regularities of sequential stimulus is necessary in order to acquire the rules of the spelling system. The spelling system is based on morpho-phonemic rules and orthographical knowledge, mostly acquired as a result of repeated exposure to written words (Ravid & Berman, 2010). Identifying regularities of letters in written words leads to the creation of spelling representation in the orthographic memory (Ise et al., 2012; Steffler, 2001; Graham, 2000).

Furthermore, the performance of the poor spellers was significantly lower in the implicit task in both experiments compared to that of the skilled spellers, supporting

the hypothesis that the poor spellers' lowered ability in spelling is derived from a difficulty in implicit learning of statistical regularities, when exposed to written words.

The decline in the performance of implicit sequential learning is significant when it comes to the development of the spelling system, since the established control in the rules of the written language is mostly done implicitly by exposure to words while reading (Pavlidou et al., 2009, 2010; Ise et al., 2012; Dienes & Mealor, 2013; Steffler, 2001; Graham, 2000). On the other hand, the explicit teaching of spelling rules is usually undertaken in the first years of school (Steffler, 2001; Graham, 2000). No significant differences were identified in the ability of the two study groups in explicit learning, suggesting that poor spellers use explicit learning processes adequately. This finding emphasis the importance of interventions that focus of explicit learning of spelling rules.

The comparison of learning abilities of both study groups indicated that both poor and skilled spellers exhibited greater success in the implicit task as opposed to the explicit one. This finding is consistent with other studies comparing learning abilities in the AGL task among various populations (Scoot & Dienes, 2010; Dienes & Mealor, 2013). These studies claim that differences in the level of learning are a result of the amount of cognitive resources invested, seeing as implicit learning is intuitive and takes place unconsciously, while explicit learning requires intentional learning expressed by extensive attention to the structure of the stimuli, identification of regularities, generalizations and formulation of regularities. An activation of these resources requires a more in-depth processing, indicating the importance of proper guidance and familiarization with the recurrence of stimulus to learn spelling rules. Additionally, extensive practice is required for deeper learning of the spelling regularities, leading to stable representations in the orthographic memory.