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Errorless Learning as a method of neuropsychological rehabilitation of individuals suffering from dementia in the course of Alzheimer's disease

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Summary

The following article discusses the possibility of applying a rehabilitation strategy known as Errorless Learning (EL) in patients suffering from Alzheimer's disease (AD). The authors present the issue in the context of the knowledge on the effectiveness of administering neuropsychological interventions in patients with AD. The history of the EL method development is presented as well as techniques used in its domain. The novelty of the EL methodological approach is shown. It is emphasized that EL, in contrast with the majority of neuropsychological rehabilitation strategies, has a relatively reliable theoretical basis. The remaining part of the work focuses on reviewing empirical findings concerning the effectiveness of employing Errorless Learning in rehabilitation of individuals suffering from AD, which are available in the professional literature. Factors affecting it, such as rehabilitation session organization, frequency of participants' advancements testing and a type of practiced material, are discussed. The effectiveness of EL is compared with the results of other neuropsychological rehabilitation methods. The authors of this article find that the EL strategy may increase cognitive training effectiveness and is a useful option in neuropsychological rehabilitation of patients suffering from moderate to severe Alzheimer's disease.

Key words: neuropsychological rehabilitation, errorless learning

Introduction

About 77 years passed between when Alois Alzheimer gave his groundbreaking description of clinical and pathological characteristics of a disease which afflicted his patient, Auguste D., and the modern works by Glenner, Masters and Beyreuther, which describe partial solubility of the Aβ peptide, Edman's publication concerning the basic

amino acid structure of the Aβ peptide, and Davies' discovery of the cholinergic deficit in the course of Alzheimer's disease [1]. Twenty years lapsed between the ability of amyloid aggregation analysis and performing clinical trials using compounds aimed at inhibiting this process. The clinical trials were inspired by the discovery of Hyman's group [2], which showed that human Aβ deposits in mice brains were quickly metabolized (formed and dissolved within few days). In a short period of time multiple endeavors were launched concerning the possibility of controlling these processes pharmacologically but in an overwhelming majority of cases they did not have the expected results. In general all strategies based on the anti-amyloid model showed results only if they are implemented long before the clinical phase of the disease begins. The effectiveness of anti-dementia of Alzheimer's type drugs, especially those belonging to the anti-acetylcholinesterase inhibitors (AchEl) group, is intensively discussed in the professional literature. There are reports on the positive effects of these drugs, although they indicate moderate effectiveness [3–6].

The development of knowledge on Alzheimer's disease is on the one hand impressive, but on the other hand it induces mixed feelings, because an effective way of slowing down the progression of cognitive deterioration has not yet been invented. Given the existing deadlock in the pharmacology domain, looking for other, non-pharmacological means, which would be used as a support to the drug therapy, may be of significant importance.

The majority of neuropsychological rehabilitation methods have very modest theoretical background and are too complex and difficult to verify [7]. The errorless learning method (EL) is positively distinguished from other neuropsychological rehabilitation approaches and it brings significant results, when employed properly.

The errorless learning method – an overview

The concept of errorless learning refers to a situation wherein a patient performing a task does not have any experience responding incorrectly, as the correct response is given first [8]. EL does not refer to a specific therapeutic intervention – it can be used during various tasks [9]. Research on errorless learning focuses on employing this method in rehabilitation of severe memory impairment, especially in mitigating problems with decreased word readiness [10]. The method derives from research on pigeons conducted in 1963 by Terrace, a proponent of the behaviorist approach. He discovered that pigeons trained with the errorless learning method mastered much faster differentiating visual stimuli of red and green color [11]. In 1986 Glisky, an author of the vanishing cues (VC) method, adapted the method to the neuropsychological rehabilitation ground [12, 13]. A meta-analysis of the research on EL published by Kessels and de Haan in 2003 showed its superiority over other methods [14].

The main assumption underlying the errorless learning method is an ascertainment that in some situations incorrect behavior may be self-reinforcing. Making an error while recalling a piece of information from memory may reinforce that experience of failure, which result increases task difficulty [9]. This phenomenon was pointed out by Baddeley and Wilson who, based on examinations of amnestic patients, concluded

that the explicit memory impairment from which they suffered makes them particularly susceptible to interferences arising from mistakes. Incorrect responses are encoded in the same way as correct ones, which leads to worsened memory performance. Because of this the EL method is optimal for patients with memory impairment, as it does not require using memory or filtering information [15]. Implicit memory is usually well preserved in patients with severe impairment of explicit memory and it is adjusted to induce the strongest reactions. Eliminating errors is important, because it enables the strengthening of connections constituting a representation of correct reactions [16]. In addition, patients suffering from Alzheimer's disease benefit less from traditional trial-and-error methods as they require activity of those brain regions usually affected by the disease. This group of patients benefit more from the EL method than from traditional methods [17].

An interpretation of the EL method in terms of the Hebb's model of learning can be found in the body of professional literature [18]. According to this model, learning conceived in synaptic level refers to strengthening of synaptic connections between neurons, which get activated simultaneously. At a higher level of organization Hebbian rules refer to detecting temporarily correlated input data. In case of the EL method the input data are: a stimulus (question) and a reaction (response). If patients are allowed to respond incorrectly, it reinforces their tendency for erroneous reactions. However, if incorrect responses are prevented and only correct ones are enabled (by the means of hints and prompts); the synaptic connections responsible for the correct responses are strengthened. The assertion that the efficiency of synaptic connections is the basis for learning and memory is one of the fundamental concepts of neuroscience.

Rehabilitation strategies used in the errorless learning method

Errorless learning should be treated as a general principle of memory rehabilitation, rather than a set of specific techniques and firmly established procedures [9, 19]. In the EL method the task difficulty is gradually increased, even if it means including some errors. It is done this way in order to gradually approximate to natural conditions and to sustain the patient's attention and make them put more effort into the task. Tasks are divided into simple steps which are repeated again and again. The complete elimination of errors is extremely difficult to achieve [20]. Most of the errorless learning-based therapies may be qualified as error-reducing approaches [9].

In EL reduction of the occurrences of errors is achieved through: (1) dividing a task into simple steps, (2) thorough modeling of the execution of a task before a patient performs it themselves, (3) encouraging the patient to avoid guessing, (4) immediate correction of errors, (5) guidelines suppression [11, 21]. The techniques themselves may vary very significantly and therefore may not be comparable. Usually, either a complete response is provided at the beginning and then its elements are removed one by one, or the task is started with one element and then it is gradually developed up to the complete response [22].

Five rehabilitation strategies which employ EL assumptions have been developed. In terms of effectiveness, these strategies vary depending on the patient population they are administered to [23–26]:

1. Within the framework of the feed-forward instruction approach, a clinician conducting a rehabilitation session gives verbal and/or manual hints to a patient, before the patient starts performing the task or prior to each step of the task composed of an action sequence.
2. In the modeling technique, a therapist demonstrates the task to completion before a patient begins to perform it. In the case of a sequential task only its current stage is presented. A patient practices it until the patient learns to perform it correctly. As the patient masters each respective step, consecutive stages are demonstrated and practiced.
3. Physical assistance refers to an approach where a clinician provides direct physical assistance at each stage of the task (e.g., the clinician helps select a correct picture by directing the patient's hand etc.).
4. Task variables modification – a therapist reduces the task difficulty by manipulating one of its variables (the therapist can, for example, give more time to complete the task). When a patient masters the task in its simplified version and performs it without errors, the difficulty level is gradually increased.
5. Spaced-retrieval – based on the subject's performance, the time gap between the task demonstration and its execution is lengthened (if it is completed correctly) or shortened (when a patient experiences difficulty). A clinician noticing a patient struggling should immediately provide a correct response or indicate which response is appropriate and have the patient repeat it.

Factors affecting the effectiveness of the errorless learning-based rehabilitation in patients suffering from Alzheimer's disease

Much of the literature on the effectiveness of errorless learning focuses on demonstrating how patients learn very specific details and often ignores the issue of additional information or more general knowledge which could be acquired in the rehabilitation process if appropriate standards were followed [14, 15, 27].

1. Training sessions organization effect on the effectiveness of the errorless learning method

The manner in which the sessions are organized, their frequency, and strategy of presenting stimuli play an important role. Re-learning lost abilities and skills is the most effective when training sessions occur on a daily basis, not a few times a week. In principle – the more the better [9, 28].

The effectiveness of EL may be improved by enabling a patient to participate actively in the training material encoding phase. Recall is more efficient when information is learned in a consistent semantic context [13, 20]. EL techniques are more effective when they require the biggest effort in the encoding phase and the patient's

more active participation. Increasing the amount of invested effort does not bring positive results in the case of already known associations, although the results are more visible when new associations are acquired in the context of assisted recalling [29]. Other research shows that semantic elaboration of a stimulus is conducive to better memorizing [30] and hints generated by a patient are more effective than those provided by the experimenter [31]. It is recommended that instructions given during rehabilitation sessions do not refer directly to the learnt information, but induce automatic recall. The patient should not consciously and retrospectively search his memory for the learnt information [30].

2. Frequency of testing the effectiveness of the errorless learning method

Implementing retrieval of the trained material at regular points of the session brings better results than employing long training sessions without breaks for testing. The effect is especially noticeable when delayed testing is used [32]. The results from mass training sessions (i.e., without pausing to test the effects) are similar to the results of sessions with testing breaks when compared immediately after the learning cycle concludes. However, after a one week delay the differences become statistically significant and range between 11 to 45% in favor of regularly tested groups [33–35]. It can be stated that the more often testing breaks occur the longer the trained material is retained in memory [32]. A long-term positive impact remains from the tests even when those tests result in failure, i.e., patients cannot recall the information [36, 37].

Generally, researchers agree that training plans consisting of learning in a series of sessions separated by intervals or mixing the training material with other activities result in better recalling of the learnt material compared with so-called mass training plans. The mass training plans which lead to the best short-term results are associated with worse retention of the learnt material in a patient's memory.

3. The trained material type and errorless learning effectiveness

The possibility of using errorless learning-based learning of activities in daily living (ADL) by patients suffering from Alzheimer's disease has been investigated [23]. It was assumed that memories, which are saved in implicit memory, are created over the course of repeated practice and do not require an individual's conscious mastering of task rules. When a patient learns an activity in an implicit way, a relatively stable change in their knowledge and behavior is noticed, whereas the patient may not be aware of what and how he/she learnt. Advantageous effects have been observed in patients with AD not only in the case of artificial, experimental tasks, but also when real ADL were the subject of training, provided that they were trained in a way conducive to encoding in implicit memory [38, 39].

Employing EL brings positive results when training AD patients with activities such as operating a cell phone, preparing a meal in a more independent way, finding one's way to a specific location within a therapeutic site, as well as performing instrumental

activities of daily living [23, 24, 32, 40, 41]. Due to the fact that errors are eliminated or reduced in the course of training sessions, patients are successful throughout the duration of the session, which decreases their frustration and increases their willingness to participate in the training [23].

A lot seems to depend on the novelty aspect of the knowledge conveyed to patients – if it is new or already known to them. EL requires basic pre-exposition to stimuli. Research suggests that residual knowledge facilitates the acquisition of semantic knowledge – both in Alzheimer's disease as well as in semantic dementia [22]. The second important factor is a patient's motivation. The authors of rehabilitation programs, who cite research conducted by Terrace in the 1960s, should remember that he had to starve the pigeons so that they maintained only 80% of their normal body weight and even under such conditions it was still difficult to obtain effect of learning. Another factor is individual meaning of the stimuli used in training (e.g., learning patient's family members' names may be more attractive than learning abstract or strangers' names) [11].

Tasks and situations which are conducive to retrieving the learned material from implicit memory (e.g., learning names by giving the first letter as a hint) benefit more from using the EL method compared to approaches based on explicit retrieval of new associations (e.g., learning how to set up an electronic calendar), in which case no effects of the EL method were observed [27].

A relationship has been established between memory impairment severity and the errorless learning method effectiveness. The EL method is more beneficial for deeply amnesic patients than for those with milder memory impairments. Such a relationship occurs provided that breaks between learning and recalling phases are relatively short [11, 13, 14, 42]. In terms of everyday practice, a more positive reception of errorless learning-based rehabilitation is noticed among more severely cognitively impaired patients. The relatively uniform and monotonous course of the rehabilitation sessions may be tiresome for less cognitively impaired patients [19, 43].

There are available reports on employing the EL method in procedural learning of AD patients [44]. Procedural learning consists of acquiring cognitive, perceptual and perceptual-motor skills through practice. It is relatively well preserved in the mild and moderate stages of AD. It has been shown that EL allows automatizing procedures faster when compared with the trial-and-error approach.

4. Effectiveness of the errorless learning method compared with other approaches to memory rehabilitation (trial-and-error, spaced-retrieval and vanishing cues)

It was proven in the 1990s in a series of case studies of patients with various neurological damages that errorless learning-based therapies were better than trial-and-error methods. Such superiority was shown in a series of tasks involving learning the names of people and places, orientation training and electronic aids programming [45]. In the literature there are two popular theories which explain the positive influence of EL [14, 28]. According to the former one, the better results are due to implicit memory

support; the latter claims that so-called residual episodic memory contributes to this phenomenon. Researchers who are inclined to accept the latter theory [27] present the argument that no benefits of using EL in element matching and free recall tasks were observed. They claim that it can be explained by the fact that EL is more beneficial than trial-and-error methods when the learning effects are tested in a way which is conducive to implicit knowledge or procedural memory engagement. In these terms the source of the errorless learning superiority is its ability to reduce interference in the course of implicit learning level but not of explicit learning. Implicit learning requires the biggest possible similarity of the input and output conditions and because of that free recall of new associations does not provide a context in which such a memory function mode could be utilized.

Research comparing the effectiveness of errorless learning with traditional trial-and-error approaches does not always bring unequivocally positive results in favor of EL [30, 46, 47]. Nonetheless, it was proven that EL methods significantly reduce a number of errors made by patients in the course of training and that EL methods help AD patients acquire semantic knowledge [48].

Research on the effects of employing spaced-retrieval in patients with dementia suggests that this method, when combined with the EL, is an effective means of cognitive rehabilitation of patients suffering from dementia [49]. Classic trial-and-error methods may temporary slow the cognitive deterioration rate in Alzheimer's disease prodromal phase, however, they may bring side-effects later because they require effort and concentration, what may pose a challenge for patients with dementia. Therefore the spaced-retrieval method may be technique especially useful in rehabilitation of patients with pronounced cognitive impairment because it does not require a noticeable effort.

Kessels and de Haan [14] compared errorless learning with vanishing cues. They demonstrated statistically significant effects for the EL and a lack of such effects in the case of the vanishing cues method. The authors explain the results by a fact that the vanishing cues method may lead to patient error because it requires sustained attention and engagement, which reduces the number of errors, but does not eliminate them. Thus, it better resembles the traditional learning approaches which involve making errors. Interestingly, patients with the most severely impaired memory benefited more in terms of learning efficiency compared to patients with less pronounced cognitive deficits.

It can be stated that errorless learning is most effective when utilized under the following conditions: (1) only a single cognitive domain or a single behavior engagement is required, (2) complex tasks are divided into simple steps, (3) tasks do not require reaction flexibility, (4) task execution requires attention only in regards to correct responses, (5) task/response should be available beforehand in the patient's behavioral repertoire. If a task/response is new, it should be introduced first via pre-training on this behavior [20].

Recapitulation

The advantages and limitations of the rehabilitation strategy known as errorless learning have been reviewed. The strong asset of this strategy, especially from a scientific point of view, is its theoretical foundation which, along with the application technique characterized by the ease of selecting quantitative parameters, helps design rehabilitation sessions which are transparent and easy to replicate. It may be useful for practitioners to know that the aforementioned method is especially well-fitted to patients in moderate or even severe stages of dementia. It can be successfully used to improve memory ability, language and everyday function as well. It should be kept in mind, however, that it is implicit memory-based, so it will not bring expected results in tasks when conscious retrieval of information from long term memory is required. The patient's comfort should be the primary premise for selecting the methods for error reduction because all five of them are equally effective as per current research. In order to maximize the benefits of rehabilitation, therapists should rely on knowledge which patients possessed in the past (e.g., family members' names or using a cell phone known to the patient previously), rather than trying to help them learn something completely new. An advantage of errorless learning is that it can be used both individually and in group settings – the latter version being more effective. To summarize, it is an approach which in clinical practice allows one to obtain real, measurable results, especially when integrated with pharmacological treatment. Clear and transparent theoretical structure of EL and easy operationalization of variables help design interesting scientific research.

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