CATÓLICA
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LISBOA · PORTO

THE IMPACT OF EDUCATION IN THE PRIMACY AND RECENCY EFFECTS IN COGNITIVELY HEALTHY AGING

Dissertação apresentada à Universidade Católica Portuguesa para obtenção do grau de mestre em Neuropsicologia

Por
Sofia Areias Marques

(Lisboa, 2022)

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O IMPACTO DA ESCOLARIDADE NOS EFEITOS DE PRIMAZIA E RECÊNCIA NO ENVELHECIMENTO NORMAL

Dissertação apresentada à Universidade Católica Portuguesa para obtenção do grau de mestre em Neuropsicologia

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Sob orientação de Professora Doutora Raquel Lemos e Professora Doutora Filipa Ribeiro

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CONTENTS

ABBREVIATIONS

AD - Alzheimer’s Disease

AVLT - Auditory-Verbal Learning Test

AWLT - Auditory Word List Learning Test

byFDT - Behavioural Variant Frontotemporal Dementia

CVLT-II - California Verbal Learning Test-II

EM - Explicit memory

fvFTD - Frontal Variant of Frontotemporal Dementia

G1: Group 1

G2: Group 2

G3: Group 3

G4: Group 4

GDS-15 - Geriatric Depression Scale – 15

HVLT-R - Hopkins Verbal Learning Test—Revised

IM - Implicit memory

LBD - Lewy Body Disease

LTM - Long-term memory

LTS - Long-term Store

MCI - Mild Cognitive Impairment

MM - Multistore Model

MoCA - Montreal Cognitive Assessment

RAVLT - Rey Auditory Verbal Learning Test

SIVD - Subcortical Ischemic Vascular Dementia

SM - Sensory Memory

SPM - Serial Position Effect

STM - Short-term Memory

STS - Short-term Store

T1: Trial 1

T2: Trial 2

T3: Trial 3

T4: Trial 4

WM - Working Memory

Abstract

The use of memory strategies can be influenced by multiple factors, some of which are still unknown. When a list of non-related words is presented for future free recall, a predictable serial position pattern appears with a better recall of words from the beginning (primacy) and from the end (recency) of the list. Primacy and recency effects have been mainly studied in cognitive impaired subjects as an attempt to understand impaired learning strategies among clinical samples. Nevertheless, this effect is very understudied in healthy groups despite its potential as a predictor of pathologic aging.

In the present study we aimed to verify if the level of education influences learning strategies (serial position effect) in a wordlist test - the Auditory Wordlist Learning Test (from the Cognitive Function Dementia/Schuhfried battery). We included 294 healthy volunteers with ages ranging from 50 to 91, distributed along 4 different education groups: 1 to 6 years; 7 to 9 years; 10 to 12 years and >12 years.

Overall, the two less educated groups presented differences from the most educated group across the four learning trials. Nevertheless, there were no differences in the learning rate. Considering serial position effects, in the first trial, the higher educated group had a clear advantage in the recall of primacy words in the first and fourth trial, as well as recency in the fourth trial. According to these results, education seems to play a role in initial learning, but has no effect in the rate of learning. Education also influenced serial position, especially primacy. Although serial position effects and learning patterns are well identified, they need further analysis in healthy groups and more consistent reproducibility in study results.

Key Words: learning, serial position, primacy, recency, memory, aging,

Resumo

A utilização de estratégias de memorização pode ser influenciada por diversos fatores, muitos dos quais não são totalmente compreendidos. Quando uma lista de palavras é apresentada para posterior evocação espontânea, pode-se identificar um padrão de posição serial nítido com melhor evocação das palavras do início (primazia) e fim (recência) da lista. O efeito de primazia e recência tem sido estudado maioritariamente em grupos com défice cognitivo na tentativa de melhor entender os seus défices nas estratégias de memorização. No entanto, este efeito ainda não está bem explorado em grupos saudáveis apesar do seu potencial enquanto preditor de envelhecimento patológico.

Neste estudo pretende-se verificar se a escolaridade tem influência na estratégia de aprendizagem (efeito de posição serial) utilizada num teste de memorização de palavras – o Auditory Wordlist Learning Test (parte da bateria Cognitive Function Dementia). Foram incluídos 294 participantes saudáveis com idades compreendidas entre os 50 e os 91 anos, distribuídos em 4 grupos de escolaridade: 1 a 6 anos; 7 a 9 anos; 10 a 12 anos e >12 anos.

Globalmente, foram encontradas diferenças significativas entre os dois grupos menos escolarizados por comparação com o grupo mais escolarizado em todos os ensaios de aprendizagem. No entanto, escolaridade parece não afetar a taxa de aprendizagem. Considerando o efeito de posição serial, o grupo mais escolarizado apresenta vantagens em relembrar palavras de primazia no primeiro e quarto ensaio, e de recência no quarto ensaio. De acordo com os resultados obtidos, o nível de educação influencia o número total de palavras memorizadas na aprendizagem, bem como o efeito de posição serial, de forma mais significativa na primazia. Padrões de aprendizagem estão bem identificados, no entanto, continua a haver necessidade de exploração destes fatores em grupos saudáveis e reprodutibilidade nos resultados.

Palavras-Chave: aprendizagem, posição em série, primazia, recência, memória, envelhecimento.

INTRODUCTION

Aging is a natural and gradual process. According to the 2001 Census and the 2007 demographic statistics, Portugal has registered, in the last decade, an increase from 13.4 to 17.4% of the elderly population with 65 years or more, representing a continued tendency to an aged population in the country. In 1995/96, the Portuguese Health Ministry (MS/DEPS, 1997) underlined that 8.8% of the people with ages between 65 and 74, and 5.9% of individuals with 75 or more years, progressively presented complaints and worsening in overall health.

With the increasing average of life expectancy, there is a growth of age-related neurodegenerative diseases and dementia. According to Prince and collaborators (2015), dementia is considered a public global health priority considering its high prevalence, economic impact, and associated stigma and social exclusion. It is estimated that there were 50 million people worldwide living with dementia in 2020 and that this number will almost double every 20 years, reaching 82 million in 2030.

Amongst all types of dementia, Alzheimer’s Disease (AD) is the most common, comprising about 60% to 70% of all the dementia cases. It represents a very significant health problem in the elderly, is comparable in incidence to the risk of myocardial and/or cerebral infarction, and it has become one of the leading causes of death in modern societies (World Health Organization, 2012). In Portugal, one of the most recent publications on prevalence, suggests that about 5.9% of the population aged ≥60 years suffers from dementia, and probably more than 80.000 persons have AD (Santana, Farinha, Freitas, Rodrigues, & Carvalho, 2015). Among the possible causal associations with dementia are low education (Nitrini & Brucki, 2021), hypertension in midlife, and smoking and diabetes across the life course (Prince, et al., 2015).

Theoretical background

Memory is central to all cognitive functions and to all human behaviour (Lezak, Howieson, Bigler, & Tranel, 2012). In a simple way, Goodwin (1989) describes memory as "*the retention of learned experiences*". It has been a focus of attention and curiosity since the early times of neuroscience and even philosophy.

Memory allows humans to use language and accumulate knowledge about the world independent of any event or prior experience (Tulving, 1985). It can be described as the process that involves acquisition and retention of information over time, and its subsequent retrieval (Glisky, 2011). Over the years, memory, and cognition in general, has gathered information from several disciplines as biology, psychology and philosophy (Squire, 2004), allowing the creation of memory function theories.

Memory Models

Many names can be associated with memory, but William James stood out as one of the first to develop a complete theory on memory functioning near the end of the XIX century. According to Portellano (2005), James's theory consists on the existence of two kinds of memory: unconscious thoughts, and thoughts that need to be brought to consciousness after a series of actions.

The existence of multiple memory systems is widely accepted (Squire, 2004) as well as the existence of several memory processes (Strauss, Sherman, & Spreen, 2006).

In the late 60's, Richard Atkinson and Richard Shiffrin (1971) focused on the optional nature of control processes. Their theory, known as the Multistore Model (MM; Figure 1) conceptualized memory in terms of stores and described its system as a flow in and out of memory, controlled by the individual. The authors described three different stores: the sensory store, that keeps limited amounts of information for a very short period of time; the short-term store (STS), that holds information longer than the previous but still has a limited capacity; and, the long-term store (LTS), that holds information for very long periods of time (maybe even perpetually) and has a large capacity. These were considered hypothetical constructs that operated as models, not directly measurable or visible and not necessarily associated with distinct structures (Sternberg & Sternberg, 2011).

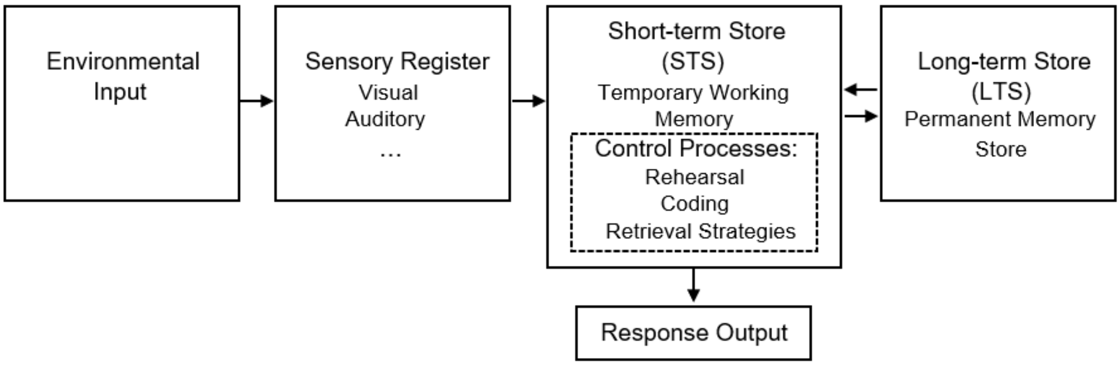

Figure 1. Atkinson and Shiffrin’s Memory Model.

Adapted from: Atkinson, R. C., & Shiffrin, R. M. (1971). The control of Short-Term Memory. Scientific American, 225(2), 82–90.

The topic of retrieval is equally important to Atkinson and Shiffrin. The main difference between retrieval from the STS and retrieval from the LTS is the time necessary for each one. The first is considered fast and accurate and the second slower and complicated given the large amount of information it contains.

Based on the Atkinson and Shiffrin (1968) model, it is possible to described three major types of memory: 1) the sensory memory (SM); 2) the short-term memory (STM); 3) the long-term memory (LTM).

1. Sensory Memory (SM)

When exposed to sensorial information, one can unconsciously ignore or perceive it. If ignored, the information disappears almost instantly but, if perceived, the sensory memory works as a buffer, retaining that information for milliseconds (Atkinson & Shiffrin, 1968). If the information is received auditorily, it is called echoic memory, and if it is received visually, it is called iconic memory (Lezak, Howieson, Bigler, & Tranel, 2012). For the uptake of sensorial information, sensory receptors are employed taking that information to a cortical level, particularly to the prefrontal cortex and parietal and inferior temporal cortex, where information is analysed and kept for a short amount of time (Strauss, Sherman, & Spreen, 2006). Due to the short storage capacity of this memory, information tends to decay very fast, unless it is given attention and subsequently moved to short-term memory (Lezak, Howieson, Bigler, & Tranel, 2012).

2. Short-term memory (STM)

Holds small amounts of information, mostly acoustic or visual, up to one minute. It is described as a temporary store for information processing, allowing recollection (Roediger, Zaromb, & Goode, 2008), and for performing mental operations on its contents (Strauss, Sherman, & Spreen, 2006). Contrarily to the previous memory, this storage needs a conscious effort to maintain the information.

Although STM and Working Memory (WM) are distinct constructs, they are often presented together. The WM, created by Alan Baddeley around 1974, refers to a set of processes for storage and manipulation of information in which STM is included (Baddeley, 2012; Sternberg & Sternberg, 2011).

The WM model consists of several elements (Figure 2): a) the visual-spatial sketchpad that holds visual and spatial information for a short amount of time; b) the episodic buffer that represents a limited capacity system for integration of episodes into multidimensional coherent “objects” or, in other words, for binding information from the visual-spatial sketchpad, the phonological loop and the long-term memory creating *episodes*; c) the phonological loop that is one of the most investigated components of WM and distinguishes between temporary store, that holds information for a few seconds, and rehearsal processes based on vocalization, that refresh the temporary store by articulatory rehearsal; and d) the central executive that is considered the most complex component of the WM and has a role on attention, processing of information, reallocation of resources, and decision making (Baddeley, 2012; Baddeley & Hitch, 2018; Sternberg & Sternberg, 2011).

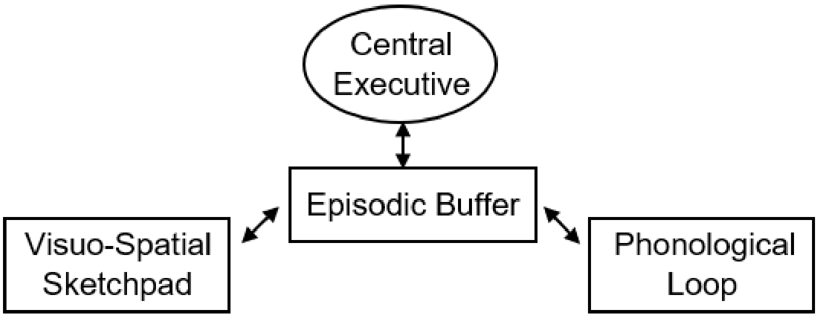

Figure 2. Baddeley's Working Memory model.

Adapted from: Baddeley, A. (2012). Working Memory: Theories, Models, and Controversies. Annual Review of Psychology, 63(1), 1–29.

According to Strauss, Sherman and Spreen (2006), ventrolateral regions are sub serving the maintenance and evaluation of representations that are kept in WM. On the other hand, dorsolateral regions are responsible for monitoring and manipulating those representations. Furthermore, the dorsolateral prefrontal cortex appears to perform functions that resemble the operations of a shared central executive.

3. Long-term memory (LTM)

After a few seconds on STM, the information can pass to LTM with the support of consolidation, rehearsal and meaningful associations (Lezak, Howieson, Bigler, & Tranel, 2012). Contrarily to STM, LTM is considered almost infinite but, although with much less significance, it is still susceptible to interference and loss of information. This memory can preserve information from all sensory registries (Atkinson, & Shiffrin, 1968).

LTM can also be subdivided according to the type of information (Figure 3): implicit (or nondeclarative) or explicit (or declarative) (Squire, 2004). Squire (2009) described explicit (or declarative) memory as expressed through recollection and implicit (or nondeclarative) memory as expressed through performance. The author also separates both memory types according to their indirect influence: the declarative memory as most relevant in skill and habit learning and the nondeclarative memory as especially important in unconsciously modifying behaviours.

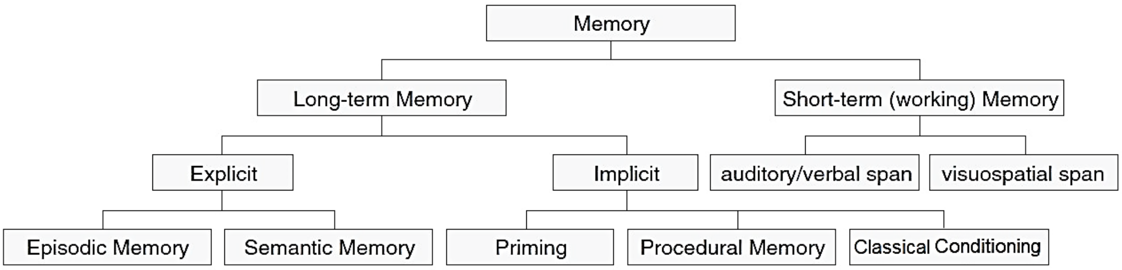

Figure 3. Taxonomy of memory systems.

Adapted from: Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary (3rd ed.). Oxford University Press

Implicit memory (IM) is non-conscious and refers to information on how to do things, allowing the automatic performance of motor actions (Lezak, Howieson, Bigler, & Tranel, 2012). IM can be subdivided into:

a. Priming, that concerns the ability to identify or process information from an early encounter with said information (Baddeley, 2002).
b. Procedural, involving motor competences. The “how to” of learning (Lezak, Howieson, Bigler, & Tranel, 2012).
c. Classical conditioning that refers to the response given to a learned stimulus (conditioned) through association with another (unconditioned) (Goodwin, 1989).

Explicit memory (EM or declarative memory): is, as the name expresses, an explicit type of memory. It refers to the information that can be consciously recalled as are facts and events (Strauss, Sherman, & Spreen, 2006). EM can be further subdivided into:

a) Semantic memory, that concerns facts and knowledge about the external world independently of time or context (Squire, Knowlton, & Musen, 1993).

b) Episodic memory, regarding autobiographic events and experiences, placing them chronologically (Greenberg & Verfaellie, 2010).

In LTM, the limbic system, and in concrete the Papez circuit is frequently portrayed as being very much involved in the formation of episodic memories and the creation of new memory traces (Hendelman, 2016; Zeidman & Maguire, 2016). The Papez circuit is constituted by the hippocampus, the fornix, the mamillar bodies and the cingulate gyrus (Figure 4) (Gil, 2010). These brain medial temporal regions are involved in declarative memory, especially in episodic memory (Squire, 2004).

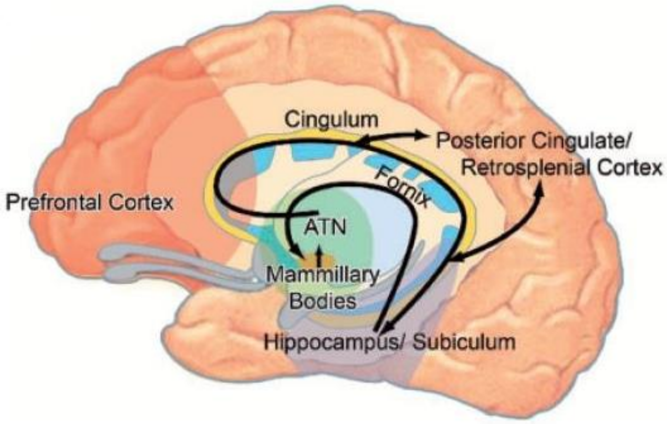

Figure 4: Schematic drawing of Papez circuit (in black).

ATN = anterior thalamic nuclei.

Source: Aggleton, J. P., Pralus, A., Nelson, A. J. D., & Hornberger, M. (2016). Thalamic pathology and memory loss in early Alzheimer's disease: Moving the focus from the medial temporal lobe to Papez circuit. Brain, 139(7), 1877–1890. https://doi.org/10.1093/brain/aww083

The role of the hippocampus in memory is unequivocal, through the description of the severe amnesic deficit of the HM patient (Milner, Corkin, & Teuber, 1968; Squire, 2009b). HM was a patient with memory loss for events subsequent to his bilateral medial temporal lobe resection (Scoville & Milner, 1957). As a persistent topic of study, the hippocampus showed itself as relevant in the storage of new information (Gazzaniga & Mangun, 2014), consolidation (Portellano, 2005; Strauss, Sherman, & Spreen, 2006) and retrieval (Moscovitch et al., 2005). In fact, for Bigbee (2011), this nucleus has a leading role in almost all memory processes as it seems to be the beginning and ending point for most memory connections. Therefore, damage to the hippocampus and its interactions have an important negative impact in memory and leaning (Deweer et al., 1995; Eichenbaum, 2017; Moscovitch et al., 2005).

Although the discussion about memory functioning remains there are some widely accepted notions. The existence of multiple memory systems is one of them (Squire, 2004).

Memory Processes

It is accepted – although not fully understood – that memory processes can assume many different forms and involve different neural systems as well as cellular changes (Nadel & Hardt, 2011). According to Baddeley (2002) different stages of memory formation follow a defined sequence (Figure 5): a stimulus is perceived and must be encoded in order to be consolidated. After that, it must be held in storage for then, when needed, be recalled.

Figure 5. Memory processes scheme.

Adapted from: Baddeley, A. (2002). The Psychology of Memory. In A. Baddeley, M.D. Kopelman & B.A. Wilson (Eds.), The Handbook of Memory Disorders (2nd ed); and Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. (Eds.), (2012). Neuropsychological Assessment (5th ed.). Oxford University Press

The encoding stage enables the registration of new information and is particularly important for the prediction of successful retrieval. This process starts with attention and is then analysed, compared, and associated with past information (Atkinson & Shiffrin, 1968; Baddeley, 2002).

Consolidation refers to the maintenance of information after acquisition and encoding. This process is recognised as central in the organization of the brain and its connections and allows the creation of robust representations of information (Tranel & Damasio, 2002). Consolidation can be involved in two different levels: first, it has a role on the creation of permanent engrams in short-term memory (Nadel & Hardt, 2011); and secondly, consolidation is involved in longer and more dynamic processes that are closely linked to hippocampal dependence/independence during long periods of time (Squire, 2009a). In fact, the hippocampus showed to be essential for memory consolidation (Eichenbaum, 2017; Willis & Haines, 2018).

Storage reflects the process necessary to stabilize the information on the brain, in other words, it is responsible for the maintenance of information through time. This process and its functionality can be measured through forgetting (Baddeley, 2022).

Lastly, recall/retrieval is the final memory process. It represents the re-assessing of information (nerve pathways) previously encoded and stored (Tranel & Damasio, 2002). This event can happen through recognition or recall: the first corresponds to an association of information with what was previously experienced and is dependent on their comparison; the second describes the recall of a fact or object and entails a more direct access to information stored (Baddeley, 2002; Lezak, Howieson, Bigler, & Tranel, 2012).

Learning

According to Lezak and colleagues (2012), although learning and memory are to some extent related and dependent on each other, they are distinct concepts. Learning corresponds to the acquisition of information and is established through the memory processes (encoding, consolidation and recall).

Herman Ebbinghaus developed a scientific approach to memory that led to several crucial findings. One of them is the concept of a learning curve that was focused on information savings (Ebbinghaus, 1885). The learning curve represents an improvement in performance in general, across multiple recall trials

(Benedict, Schretlen, Groninger, & Brandt, 1998; Strauss, Sherman, & Spreen, 2006) with continued presentations of the same information. As a result of this continued presentation, encoding and retrieval from LTM will be facilitated (Lezak, Howieson, Bigler, & Tranel, 2012). Learning through practice can depend on two different elements: the total-time devoted to the learning and the distributed-practice effect. This effect states that spread learning trials over time is more effective (Matlin, 2009).

Mnemonics are the most well-known strategies resorting to verbal, visual or auditory associations to easily remember new material (Baddeley, 2002). These can mainly be approached through an imagery perspective or, by contrast, through an organization standpoint. The first one is achieved by mentally representing objects or actions using the keyword method (for example, identifying words similar to the one that must be learned) or the *method of loci*, where items are associated with visual images of physical locations (Sternberg & Sternberg, 2011). The second occurs when attempting to systematically organize new information (Matlin, 2009) and this strategy can take several forms:

- Chunking: the process in which several small units are combined into larger ones. Several studies have found that new material is better recalled when grouped in familiar units (Bower & Springston, 1970). One theory that brought the most attention to chunking was “The magical number seven, plus or minus two” presented by George A. Miller (1956), that states that short-term memory has a capacity of seven plus-or-minus two chunks of information. The author further said that it is possible to increase short-term memory by creating chunks of items.
- Hierarchy: a system that organizes new information in a series of classes from general to specific (Eichenbaum, 2017).
- First-letter technique: using the first letter from a word to compose another word or sentence: though this seems to be a frequently used technique its efficacy is not clear (Herrmann, Raybeck, & Gruneberg, 2002).

- Narrative technique: resorting to stories as a way of linking words together. In contrast to the first-letter technique, the narrative seems to be a successful strategy (Wilson, 2002).

Opting for a learning strategy is not always straightforward. As described by Atkinson and Shiffrin (1971), during learning, systematically changing memory strategies can be advantageous as it potentiates retrieval. Nonetheless, it is more time consuming than a random option, that is not always as successful.

Serial Position Effect (SPE)

Studies on learning have continually showed the existence of a learning curve in exponential form (Murdock, 1960). This is particularly true when talking about immediate free recall (Davis et al., 2003) of a list of items, such as words, that exceed the attention span (Howieson et al., 2011). This learning curve represents a very consistent learning pattern: the serial position effect (Ebbinghaus, 1885).

This effect was initially proposed by Hermann Ebbinghaus (1885) and can be described as the probability of recalling items of a list according to their position. According to this effect, a *U*-shaped curve is obtained (Figure 6) revealing a preference for primacy words – words on the beginning of the list -, and recency words – words from the end of the list – when compared with the words in the middle of the list (Deese & Kaufman, 1957; Lezak, Howieson, Bigler, & Tranel, 2012; Murdock, 1962).

The serial position effect has been linked to different influencing factors, from wordlist length in neuropsychological tests (Grenfell-Essam & Ward, 2012; Henson, 1998), to the type of memory used in free recall (Craik & Lockhart, 1972). There seems to be evidence that the primacy effect is closely related to long-term memory and the recency effect to short-term memory (Davis et al., 2003; Howieson et al., 2011; Massman, Delis, & Butters, 1993). Talmi and colleagues (2005) analysed the neural correlates of the serial position effect. The authors found that the early (primacy) items activated brain areas associated with LTM (within the hippocampal memory system) but none were activated during the retrieval of recency items.

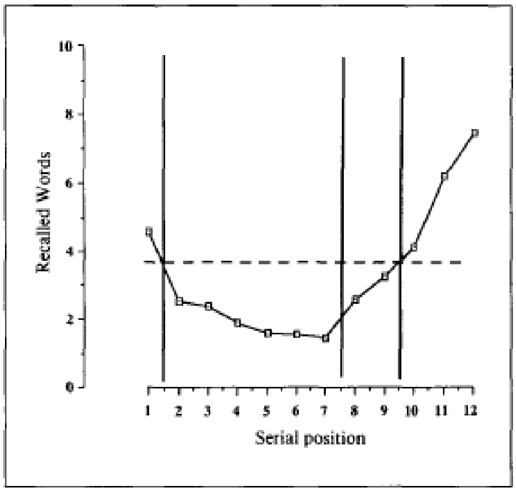

Figure 6. Number of recalled words as a function of serial position for free verbal recall.

Source: Capitani, E., Della Sala, S., Logie, R. H., & Spinnler, H. (1992). Recency, Primacy, and Memory: Reappraising and Standardising the Serial Position Curve. Cortex, 28(3), 315–342. https://doi.org/10.1016/S0010-9452(13)80143-8

While the relationship between primacy and LTM is well accepted, the relationship between recency and STM is more debatable (Glanzer & Cunitz, 1966). Griffin and collegues (2017) justified the relationship between primacy and LTM with the probability of rehearsal: in a list, the first words presented have more opportunities for practice and, by consequence, higher probability of being transferred to the long-term store. By contrast, the last words do not have the same opportunity for repetition and, thus, their retrieval represents the output of STM (Carlesimo, Sabbadini, Fadda, & Caltagirone, 1995).

In 1976, Goodwin performed a memory task to study the influence of practice in primacy and recency in single trial free recalls. The author found that both primacy and recency change as a function of practice – the more the participants were presented with wordlists, the more primacy and recency changed. For Goodwin, the recency increases with practice according to changes in retrieval strategy, whereas primacy decreases as a result of inter-list proactive interference. Furthermore, this seems to be especially true when using several wordlists for the evaluation of serial position effect.

Evidence for the relationship between primacy recall and LTM and recency and STR also comes from clinical samples: the increased forgetting in AD patients seems to be a result of a deficit in memory consolidation mechanisms that prevents the last items of a list from being transferred from a temporary STM to a stable LTM storage (Turchetta, et al., 2018).

Wordlist tests are one of the most exploited ways of evaluating learning, memory, and, thus, serial position effect (Ranjith, 2012). These tests potentiate access to the effectiveness of learning through several types of recall: 1) free, when a list can be recalled in any order, revealing serial position effects; 2) cued, when the task requires remembering through cues or guides; 3) serial, when the task implies the recall of words in the order in which they were presented (Baddeley, 2002).

The wordlists used in neuropsychological evaluation are composed mostly by unrelated words with similar psycholinguistic characteristics (Lezak, Howieson, Bigler, & Tranel, 2012) such as word length, word frequency and neighbourhood size (Hessler, Brieber, Egle, Mandler, & Jahn, 2017). Some of the most known wordlist tests to assess episodic memory are the Auditory-Verbal Learning Test (AVLT; Claparède cited by Boake, 2000), that was later adapted into the Rey Auditory Verbal Learning Test (RAVLT; Schmidt, 1996), the California Verbal Learning Test-II (CVLT-II; Woods, Delis, Scott, Kramer, & Holdnack, 2006), and the Hopkins Verbal Learning Test—Revised (HVLT-R; Benedict, Schretlen, Groninger, & Brandt, 1998).

The lists that require recall of semantically unrelated information, such as the RAVLT, are thought to be more difficult than story recall tasks or semantically related word lists because they require more effortful strategies for encoding and retrieval (Strauss, Sherman, & Spreen, 2006). Accordingly, these unrelated wordlist tests are some of the most used when evaluating episodic memory (Lezak, Howieson, Bigler, & Tranel, 2012) and, consequently, many of them are adapted, normalized and validated to provide more accurate results. When normalizing and validating wordlist tests, sociodemographic characteristics and their impact on performance are analysed.

Regarding the sociodemographic characteristics, age is described as a factor that can affect cognitive performance (Firmino, Simões, Pinho, Cerejeira, & Martins, 2018). Particularly, in wordlist tests such as RAVLT, CVLT-II, or HVLT-R, this influence expresses poorer performance with increasing age (Strauss, Sherman, & Spreen, 2006). Sex is also frequently described as an influencing factor on performance with women showing frequently better results (Lezak, Howieson, Bigler, & Tranel, 2012). Similarly, the level of education proved also to influence the results on wordlist tests with less educated people performing poorer. Such results were found in the CVLT-II (Strauss, Sherman, & Spreen, 2006), HVLT-R (Strauss, Sherman, & Spreen, 2006), and in the AVLT (Lezak, Howieson, Bigler, & Tranel, 2012). Accordingly, these sociodemographic characteristics have the ability to influence test results and, thus, are considered and tested when creating scoring systems. And that is why test norms are distributed according to demographics.

As previously mentioned, the serial position effect is present in immediate free recall (Davis et al., 2003) of wordlists. Because of its easy replicability, the analysis of this effect can be useful when analysing the validity of list-learning tasks (Lezak, Howieson, Bigler, & Tranel, 2012). Furthermore, it can also be used as a proxy of memory function in clinical practice due to its capability to discriminate dementia types (Capitani, Della Sala, Logie, & Spinnler, 1992), hippocampal health (Bruno et al., 2015) and generalized cognitive ability (Bruno et al., 2016).

Murdock (1962) was one of the first to investigate the serial position curve of free recall using wordlists. His work tried to show, with no success, that the serial position curve would change as a function of list length. In fact, Murdock (1962) concluded that, for almost all wordlist lengths used, the serial position curve could be characterized similarly: a steep primacy, an S shaped recency effect and a horizontal asymptote for the middle words. The author explains this lack of difference with proactive and retroactive inhibition effects that occur within the list itself. Moreover, having advanced knowledge of the list length does not seem to influence the recall performance (Grenfell-Essam & Ward, 2012).

Grenfell-Essam, Hogervorst and Rahardji, (2017) performed an in-depth analysis of the recall patterns in the HVLT with special focus on serial position effect and the learning curve. The authors found that the linguistic characteristics of the wordlists - word frequency, word length and orthographic neighbourhood -, did not reveal significant differences on the recall performance.

Contrarily, Ward, Tan, and Grenfell-Essam (2010), in a study about the effects of list length and output order in free and immediate serial recall, revealed that list length can influence the first word recalled and, consequently, the serial position curve: when recall starts at the beginning of the list, there is an elevated recall of early list items; when recall starts toward the end of the list, there is extended recency effects. Ward & Tan (2019) complement this discussion by showing that there is some control over the input order and that different retrieval strategies exist for rapidly searching for different numbers of items from immediate memory, thus changing the recall patterns in small wordlists.

These differences in results highlight the lack of evidence and reproducibility when analysing serial position effects and its influencing factors.

When considering clinical groups, the assessment of immediate free recall has been broadly tested. Despite not being fully consensual, some relevant patterns have been found and highlight the pertinence of assessing serial position effect in these groups (Massman, Delis, & Butters, 1993).

Most studies of serial position effect in clinical groups focus on AD its comparison with other dementias, Mild Cognitive Impairment (MCI) or healthy groups.

In AD, there are several studies demonstrating that serial position is altered and can be generally characterized by an attenuation of primacy (Burkart, Heun, & Benkert, 1998; Morris & Baddeley, 1988).

Comparisons between AD and other dementia types show that AD and a mixed etiology group present a similar recall pattern of diminished primacy (when comparing with middle and recency portions of a list), but vascular dementia did not show such patterns (Orru et al., 2009); regarding the behavioural variant of frontotemporal dementia (bvFTD, Kloth and collegues (2020) go further by stating that a recency dominance index from a single, 15-item word list memory trial, can assist in the discrimination of patients with AD from patients with bvFTD, even if both groups present a similar severe memory impairment.

Nevertheless, not all studies have been able to reproduce these findings and the pattern of lower primacy effect in AD patients. A study conducted by Turchetta and colleagues (2018) comparing AD and the frontal variant of frontotemporal dementia (fvFTD), Lewy body disease (LBD) and subcortical ischemic vascular dementia (SIVD) groups, showed that the recency portion of the list emerged as the differentiating factor. More specifically, AD patients demonstrated an increased forgetting in the recency portion of the list and similar forgetting rates on the primacy and middle portions as the other dementia patients.

A great number of studies have also been published comparing AD and MCI pathologies, more specifically, analysing recall patterns. Accordingly, several measures of verbal memory in delayed recall are identified as good predictors of conversion from MCI to AD (Gainotti, Quaranta, Vita, & Marra, 2014). The serial position effect is one of those variables capable of predicting conversion to more severe states of cognitive impairment (Egli et al., 2014). Similarly to AD, MCI patients seem to have a diminished primacy effect (Howieson et al., 2011). Nonetheless, when directly comparing MCI and AD groups, the MCI subjects' ability to recall primacy and middle words comes closer to that of normal subjects, while their memory of recency words is poor, much like in AD (Martín et al., 2013). Cunha and collaborators (2012), in a longitudinal study using the word recall task of the Alzheimer's Disease Assessment Scale–Cognitive, concluded that the primacy effect improved the discrimination between MCI and controls and between MCI who did not progress to AD and MCI who did, proving to be more sensitive and specific than the recency effect. Likewise, in MCI participants who converted to AD over 18 months after baseline, only the serial position variables capturing poor primacy item recall predicted conversion. This suggests that a measure of serial position learning, such as primacy, is a preferred predictor for conversion of MCI to AD (Egli et al., 2014).

Although these alterations are found in clinical groups after diagnosis, for many dementia types and especially in AD, the verbal memory deficits appear years before a diagnosis (Albert, Moss, Tanzi, & Jones, 2001).

Similarly to AD, MCI has also been studied in regards to serial position effect. The comparison between different types of MCI showed that, in the multiple-domain amnestic MCI subtype the primacy effect was lower, and in the single domain amnestic MCI groups the recency effect was higher (Campos-Magdaleno, Díaz-Bóveda, Juncos-Rabadán, Facal, & Pereiro, 2016). When compared to controls, MCI groups' serial positions also present diminished primacy effects relative to recency (Howieson et al., 2011).

The study of recall patterns in healthy subjects is not so prominent when comparing to clinical groups. Nevertheless, recently, the interest in studying it has increased.

In tests such as the AVLT, younger age, ethnicity and higher levels of education seem to be associated with better performance (Uchiyama, et al., 1995). Looking specifically into age, many aspects of free recall seem to be impaired and the variance measurement of recall shows greater inter-individual differences with increasing age (Davis et al., 2003).

Bolla-Wilson and Bleecker (1986), used the RAVLT to compare demographic factor’s influence in the recall. They found that sex (woman > men) and verbal intelligence (high > low) correlate more with better performance than age or education, that showed no relationship. In fact, verbal intelligence and sex were responsible for a significant variance in performance on every learning trial. Higher verbal intelligence was related to better performance and women performed consistently better than men, while age was only related to performance on the first trials.

When looking into more specific research of learning and serial position effect in healthy populations and their sociodemographic characteristics, the information available is leaner and more inconsistent. Most studies available focus on exploring age, rather than sex or level of education, that is, understandably, one of the more relevant sociodemographic characteristics in the context of neurodegenerative diseases.

Mitrushina and collegues (1991) explored the effect of age on encoding, retention, and retrieval components of memory functioning with 4 different age groups of older healthy individuals. The authors found that age was related with recall but not rates of learning, forgetting or recognition. Regarding serial position, it was identified that primacy and recency were equally strong for all groups, presenting no alterations with increasing age.

Similarly, Griffin and collegues (2017) in a study about the influence of age in serial position effect, analysed trends in primacy, middle, and recency recall in younger and older groups of subjects, using the Memory Assessment Scales. The authors found an equal increase of recency and middle words over trials for the two groups while maintaining the number of primacy words stable. When looking into retention trials, both groups also showed similar primacy retention but, the older group reduced retention for middle and recency words indicating that the delayed retention differed according to age and serial position. Furthermore, because the older group had a lower baseline of initial recall, the subsequent acquisition through trials was also lower than the younger group, although both presented a similar rate of learning. The authors also considered other demographic factors and found that education played a prominent role in free recall. For the authors, the importance of education in these results can be explained by different encoding choices in the highly educated groups.

Education may have direct and indirect influence the brain's reserve in regions that are most vulnerable to the neuropathology of aging, dementia, and specifically, AD (Tang, Varmaca, Miller, & Carlson, 2017). Anstey and Christensen (2000) state that the level of education might be a main factor influencing cognitive performance in memory tests. Although research regarding the level of education and the serial position effect is not prominent, its analysis can provide better understanding of how education shapes list learning in free recall tests and allow more accurate extrapolations into clinical settings.

In the present work, we propose to evaluate if list acquisition varies according to the level of education, and if different levels of education differ in serial position effect.

Based on the literature reviewed above, we hypothesize that: 1) low educated groups will have a lower performance on the first trial of a list-learning test than higher educated ones; 2) learning slopes of list acquisition will be sharper for the higher educated groups; 3) low educated groups will have a lower performance in retention; 4) groups with lower levels of education will recollect more recency words and, by contrast, the higher educated groups will recall more primacy positioned words.

METHODS

Participants

Participants were 390 older healthy adults recruited in a Clinical Centre in Lisbon for a norming and validation study. Participants were screened for cognitive impairment using the *Montreal Cognitive Assessment* (MoCA; Nasreddine et al., 2005) Portuguese version with respective mean and standard deviation cut-off scores (Freitas, Simões, Alves, & Santana, 2011), resulting in 81 subjects excluded; and for Major Depression, using the Geriatric Depression Scale – 15 (GDS-15; Yasavage & Sheikh, 1986) Portuguese version (Simões, Prieto, Pinho, Sobral, & Firmino, 2015), where 15 participant scored positively and were also excluded.

The remaining 294 participants, from which 154 were females, were divided into 4 groups according to their educational level: Group 1: 1 to 6 years of education (*n* = 76); Group 2: 7 to 9 years of education (*n* = 102); Group 3: 10 to 12 years of education (*n* = 35) and Group 4: more than 12 years of education (*n* = 81).

All participants over 50 years old were considered, all were interviewed beforehand and excluded if previously diagnosed with any neurological or psychiatric disease, if speakers of a native language other than Portuguese, if diagnosed with any medical condition that could influence cognition, and/or if currently taking medication with a possible cognitive impact.

All subjects were submitted to the same experimental research protocol. Informed consent was obtained from all participants, and the study was conducted in accordance with the tenets of the Declaration of Helsinki, and approval of the local ethics committee.

Materials and procedures

Auditory Word List Learning Test (AWLT)

Subjects were globally assessed using the *Cognitive Function Dementia Test Set* from the *Vienna's Computerized Test System*. This is a computerized evaluation battery that comprises several cognitive domains, such as: attention; memory;

executive functioning; language and visuoconstruction tests, and lasts around one hour.

The AWLT was used to evaluate memory and learning strategies, specifically, serial position effect. It consists of a 12 non-semantically related wordlist that were previously chosen by a linguistics expert and selected according to word frequency (5-15 per million words), neighbourhood size (5-15 orthographic neighbours), extension (1-2 syllables) and syntactic classification (nouns). This test entails several parts: i) four learning trials in which a pre-recorded fixed over trials list of words is presented and asked to be repeated immediately afterwards; ii) a short-delayed free recall after a 5-minute non-verbal task; iii) a long-delayed free recall after a 20-minute interval of non-verbal tasks.

Our variables of interest were: i) the total number of correct words recalled in each learning trial; ii) primacy (the first four words of the list), middle (the middle four words), and recency (the last four words of the list), in the first and last trial of the learning sequence, to examine serial position effects; iii) short-term recall measured by the total number of words recalled after 5 minutes; iv) long-term recall measured by the total of words remembered after 20 minutes; vi) savings, calculated as the difference between short-term recall trial and trial 4; vii) retention, obtained by the difference between the total number of words remembered on the long-term delayed recall and the short-term recall trial.

Data analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 28.0) (IBM SPSS, Inc., Chicago, IL) and Prism Graphpad 8.0.1.

Considering the robustness of the sample, and, according to the central limit theorem, a normal distribution was assumed and parametric statistical methods were applied. Differences were considered significant when $p<0.05$.

Descriptive statistics were used for sample's characterization and a linear regression was conducted to assess the impact of level of education on serial position related variables. Comparisons between variables were performed with the one-way ANOVA with a Bonferroni correction and adjusted *p*-value for pairwise comparisons. The chi-squared test was used for comparisons between categorical variables.

RESULTS

Sample Characterization

All participants were adults with ages ranging from 50 to 91, divided into four groups according to educational level. The demographic characteristics of the study sample are presented in Table 1. No statistically significant differences were found on age (F(3, 290)=0.83, *p*=0.48) and sex (χ^2=1.56, *p*=0.67).

Table 1. Demographic characteristics of the four educational groups.

	Group 1 [1 – 6y] (n=76)	**Group 2 [7 – 9y] (n=102)**	**Group 3 [10 – 12y] (n=35)**	**Group 4 >12y (n=81)**	**F**	***p***
Age	64.16±9.91	65.8±9.75	66.31±10.91	64.22±9.39	0.83	0.48
Sex (female:male)	41:35	57:45	18:17	38:43	1.56	0.67

Note: All values (except for gender) are expressed as mean ± standard deviation (SD).

Learning

The analysis of the performance on the AWLT selected measures between the four groups (Table 2), showed that: in the first trial, there are differences between groups (F(3, 290)=8.56, *p*<0.001), specifically, group 1 remembered significantly less words than group 3 (*p*=0.026) and group 4 (*p*<0.001), similarly to group 2 that also remembered less words than group 4 (*p*=0.002); the other groups did not present any differences. On the second trial, consistent results were found (F(3, 290)=7.06, *p*<0.001), with the two less educated groups remembering less words when compared with the most educated group (group 1-4: *p*<0.001; group 2-4: *p*=0.01). The remaining groups presented no differences. The same pattern was found in the two subsequent trials: in trial 3 (F(3, 290)=5.45, *p*=0.001), where group 1 differed from group 4 (*p*<0.001) and group 2 differed from 4 (*p*=0.016); and in trial 4 (F(3, 290)=6.22, *p*<0.001): group 1 significantly differed from group 4 (*p*<0.001) and group 2 from group 4 (*p*=0.005).

On the short-term delayed recall all groups significantly recalled less words when compared with group 4 (F(3, 290)=7.34, *p*<0.001, specifically, group 1: *p*<0.001, group 2: *p*=0.002; and group 3: *p*=0.007). When looking for the same comparison in the long-term delayed recall trial, the difference between group 3 and group 4 was lost. On the other hand, the two less educated groups (group 1 and 2) continued to recall significantly less words than group 4 (F(3, 290)=4.48, *p*=0.004, specifically group 1: *p*=0.01; and group 2: *p*=0.01). No other differences were found on the delayed recalls. When comparing savings and retention between groups, there were no significant differences.

Table 2. Number of words recalled per group in each trial with statistical values and significance.

	Group 1	**Group 2**	**Group 3**	**Group 4**	**F**	***p***	**Groups**
T1	3.61±1.5	3.89±1.39	4.49±1.46	4.7±1.65	8.55	0.026 <0.001 0.002	G1<G3 G1<G4 G2<G4
T2	6.22±1.74	6.64.03±1.75	7.14±1.96	7.52±2.07	7.06	<0.001 0.01	G1<G4 G2<G4
T3	7.66±1.91	7.96±1.76	8.23±1.97	8.8±1.9	5.46	0.001	G1<G4 G2<G4
T4	8.32±1.73	8.57±1.95	8.54±2.21	9.52±1.81	6.22	<0.001 0.005	G1<G4 G2<G4
STR	6.97±2.21	7.25±2.24	6.97±2.37	8.41±1.92	7.34	<0.001 0.002 0.007	G1<G4 G2<G4 G3<G4
LTR	6.79±2.32	6.87±2.4	6.97±2.71	7.99±2.22	4.48	0.01 0.01	G1<G4 G2<G4
Savings	-1.34±1.22	-1.31±1.36	-1.57±1.33	-1.11±1.65	0.94	0.42	-
Retention	-0.18±1.09	-0.38±0.95	0.00±1.06	-0.42±1.01	1.93	0.12	-

Note: All values are expressed as mean ± standard deviation (SD).

Values obtained with a one-way ANOVA and a Bonferroni correction for multiple comparisons with adjusted *p*-value.

T1: First trial of the learning phase; T2: Second trial of the learning phase; T3: third trial of the learning phase; T4: fourth trial of the learning phase; STR: Short-term recall trial; LTR: long-term recall trial. G1: group 1 (1-6y); G2: group 2 (7-9y); G3: group 3 (10-12y) and G4: group 4 (>12y).

Due to the differences found in the total number of words recalled between the groups, we were interested in further analysing the performance of each group throughout the learning trials.

A repeated measures ANOVA and Bonferroni pairwise comparisons with adjusted p-value indicated that all groups differ in the number of words recalled between trials (group 1: F(3.26, 244.61)=142.63, $p<0.001$; group 2: F(3.63, 366.55)=207.68, $p<0.001$; group 3: F(3.64, 123.74)=68.09, $p<0.001$; and group 4: F(3.88, 310)=164.37, $p<0.001$). From trial 1 to trial 2 all groups improved in the mean of words recall: group 1, $p<0.001$; group 2, $p<0.001$; group 3, $p<0.001$; and group 4: $p<0.001$. The same results were found between trial 2 and 3: group 1: $p<0.001$; group 2, $p<0.001$; group 3, $p<0.001$; and group 4, $p<0.001$. When comparing trial 3 and 4, all groups presented significant differences with the exception of group 3 that seems to have stabilized learning (group 1, 2, and 4, respectively: $p<0.001$, $p<0.001$, $p<0.001$). When comparing trial 4 with the short-term delayed recall, all groups presented a significant decrease in the number of words recalled (group 1: $p=0.004$; group 2: $p<0.001$, group 3: $p=0.004$; and group 4: $p<0.001$), and, finally, compassions between short-term recall and long-term recall showed that group 2 ($p=0.002$) and group 4 ($p=0.005$) were the only groups to present significant differences, significantly decreasing the number of words recalled.

We then looked at the groups' rate of learning (Figure 1) and found no statistically significant differences between them, based on the curve's confidence intervals. In Table 3 we can see B1 and B2 parameters for second order equation values for all the curves.

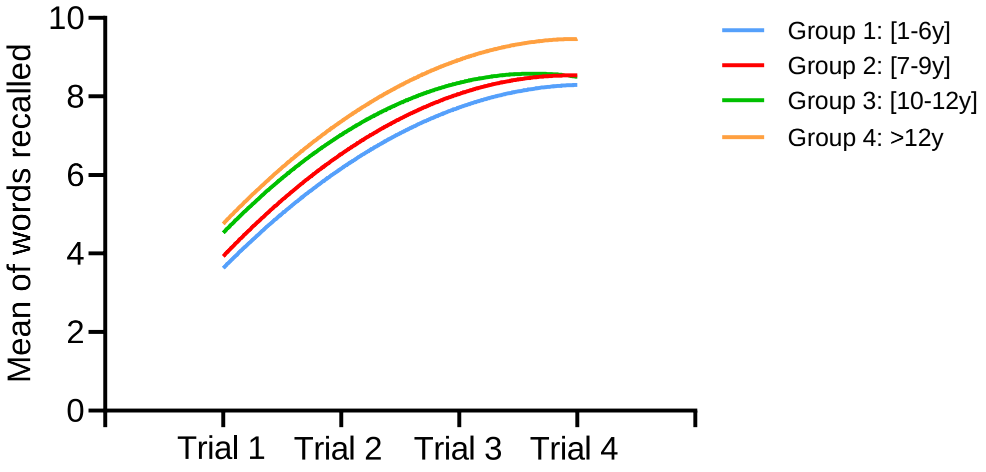

Figure 1. AWLT learning curves according to years of education.

Goodness of fit: Group 1, R^2=0.53; Group 2, R^2=0.52; Group 3, R^2=0.41; Group 4, R^2=0.49.

Table 3. Learning curve parameters for the second order equation for each educational group.

	B1	B2
Group 1	4.01 [3.02 – 5]	-0.49 [-0.68 – 0.3]
Group 2	4.21 [3.36 – 5.06]	-0.53 [-0.71 – -0.37]
Group 3	4.25 [2.63 – 5.88]	-0.59 [-0.91 – -0.27]
Group 4	4.16 [3.12 – 5.20]	-0.52 [-0.72 – -0.31]

Note: confidence interval values are represented between square brackets.

B1 and B2 represent the equation coefficients.

Serial Position Effect

As previously stated, we were interested in exploring serial position in trials 1 and 4, which represent the first and the last time the wordlist is presented. It is important to mention that the sequence of word presentation across the learning phase is always the same.

The first trial evokes a “pure” serial position effect, as it is the first presentation of a wordlist and, therefore, raises particular interest. As seen in Figure 2, in the first trial, our data confirmed the classic “U” shaped curve described as serial position effect: more words were recalled from the beginning and from the end of the word list, than the middle part, in all groups.

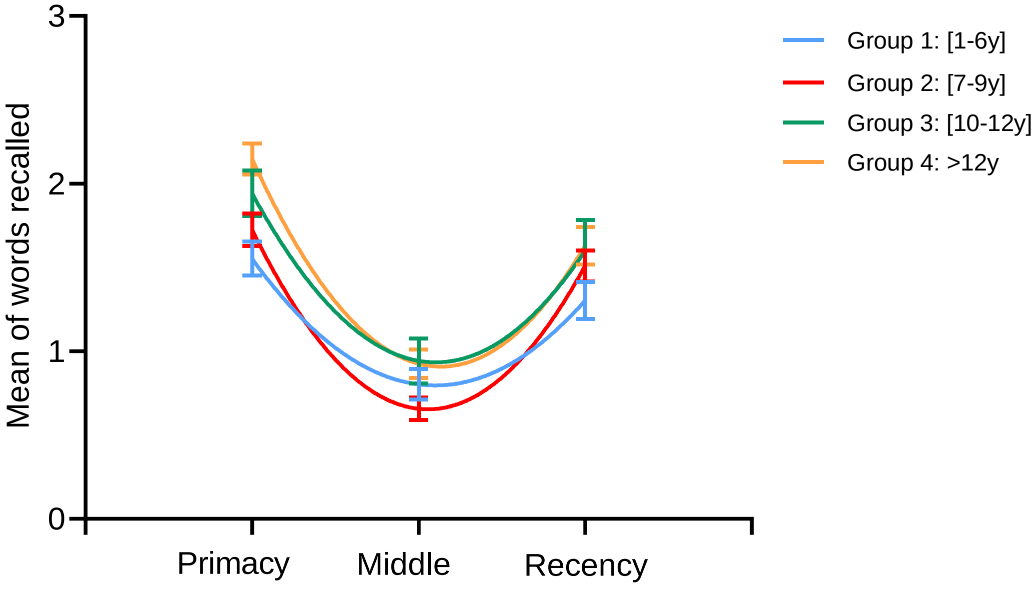

Figure 2. Mean of words and SEM of the recalled words from the primacy, middle and recency part of the list, in the first trial, for each educational group.

Trial 4 establishes the end of the learning phase and represents the end of the serial position effects applied during the process of learning and, thus, influencing memory components involved in recall and retention.

To understand if the education level impacts serial position effect, a Simple Linear Regression was performed for the first learning trial. The results indicate that level of education proved to have a significant impact serial position effect, more specifically in primacy (R^2=0.6, F(1, 292)=18.44, *p*<0.001, β=0.05, *p*<.001) and recency (R^2=0.15, F(1, 292)=4.47, *p*=0.03, β=0.03, *p*=0.04). No effect was found for the middle part of the wordlist (R^2=0.13, F(1, 292)=3.71, *p*=0.06, β=0.02, *p*=0.06).

Additionally, we were interested in checking if there were differences in the magnitude of primacy and recency effects between the education groups on trials 1 and 4. Table 4 shows that, in the first trial, the recall of primacy words differs between groups (F(3, 290)=6.41, *p*<0.001), more specifically, between group 1 and 2 when compared with group 4 (*p*<0.001 and *p*=0.011, respectively). The remaining groups present no such difference and, no differences were found in the recency portion of the list. In trial 4, the groups also presented differences, this time on both primacy (F(3, 290)=3.54, *p*<0.001) and recency (F(3, 290)=5.69, *p*<0.001). In greater detail, the lowest educated and the highest educated groups showed a significant difference in the recall of primacy words (*p*=0.018), and the two less educated groups (group 1 and 2) recalled less words from the recency part of the list when compared with the highest educated group (group 4) (*p*<0.001 and *p*=0.011, respectively).

Table 4. Percentage of words recalled from the primacy and recency part of the list on trial 1 (P1% and R1%, respectively) and trial 4 (P4% and R4%, respectively).

	Group 1	**Group 2**	**Group 3**	**Group 4**	**F**	***p***	**Groups**
P1%	0.39±0.22	0.43±0.25	0.49±0.2	0.54±0.21	6.41	<0.001 0.011	G1<G4 G2<G4
R1%	0.33±0.24	0.38±0.24	0.4±0.27	0.41±0.25	1.62	0.18	-
P4%	0.81±0.2	0.83±0.2	0.85±0.19	0.9±0.17	3.54	0.018	G1<G4
R4%	0.63±0.25	0.66±0.25	0.69±0.29	0.78±0.23	5.69	<0.001 0.011	G1<G4 G2<G4

Note: Percentage calculated from the total of words recalled for trials 1 and 4. All values are expressed as mean ± standard deviation (SD). Statistical analysis values were obtained with a one-way ANOVA and a Bonferroni correction for multiple comparisons with adjusted *p*-value.

DISCUSSION

Most studies about learning strategies and patterns, specifically in serial position effects, have mainly focused in clinical samples. Among these studies the most common goal is to find learning patterns that allow the classification of severity or, in some cases, the prediction of clinical development (Cunha, et al., 2012; Kloth, et al., 2020; Shapira-Lichter, et al., 2021). Although learning and changes in serial position effects are well described in clinical groups, there seems to be less investment in it study in healthy subjects so far and, the few papers available on the topic focus particularly on aging. Nevertheless, in healthy subjects, the identification of serial position patterns can: i) increase the knowledge about learning strategies, ii) understand the differences according to sociodemographic characteristics and, iii) detect memory deficits before clinically significant symptoms thus contributing to an early diagnosis.

The general purpose of this work was to explore trends in list acquisition and serial position effects across several healthy education groups.

Our findings first show that both the less educated groups (groups 1 and 2) had a lower baseline immediate recall (trial 1 of the list acquisition) than the highest educated group (group 4). Similarly, group 1 also presented significantly less immediate recall when compared with group 3 for the same trial. Accordingly, our first hypothesis stating that lower education groups would present less baseline recall, was confirmed. Throughout the remaining learning trials, the difference in recall followed a similar pattern: the two lower educated groups (groups 1 and 2) recalled significantly less words that the highest educated group (group 4).

Concerning the short-term delay recall trial, all groups presented a lower performance when compared to group 4 and, similarly, in the long-term delayed recall, the two less educated groups (group 1 and 2) remembered significantly less words that the highest educated group (group 4).

These results show that, during learning and during both short- and long-term delayed recalls, the less educated groups (groups 1 and 2) consistently remembered less words when compared to group 4. The first learning trial and the short-term delayed recall trial were the moments where more differences between groups were found, i. e., significant differences were found beyond the lowest and highest educational groups.

The difference between the initial recall (trial 1) and learning over trials is widely accepted. Initial recall represents the first time that a list of words is recalled, while learning concerns the improvement or performance across several trials (Spreen, & Strauss, 1998). There seems to be several factors that impact learning and, thus, overall performance in word list tasks. According to Jones and colleagues (2005), one of them is sociodemographic characteristics. The authors state that the most important impact of sociodemographic characteristics such as education is presented in the first trial. Our work corroborates this idea, since we also found differences between groups according to education.

Concerning the learning trend, in our study we found that all groups significantly increased the number of words across the learning trials, with the exception of group 3 that stabilized within the last two trials.

Furthermore, all groups recalled significantly less words in the short-term delayed recall as compared with the last learning trial (trial 4). Yet, in the long-term delayed recall, only groups 2 and 4 recall significantly less words, when compared with the short-term delayed recall trial.

Although the groups differ in the first learning trial, as well as in total recall across trials, they present similar learning rates (and learning slopes) contrarily to our prediction – second hypothesis. Since the more educated groups tend to have better performances in wordlist tests like the AVLT (Lezak, Howieson, Bigler, & Tranel, 2012), and thus recall more words, as confirmed in the present work, we hypothesised that they would show a better rate of learning compared with the other groups. In fact, our results showed the opposite. Our findings are in agreement with Griffin and colleagues (2017) that found group differences according to age only in the first trial. In fact, there is evidence that initial recall (first learning trial) is more sensitive to sociodemographic characteristics than the remaining trials and, accordingly, not differentiating the first learning trial form the total learning might confuse the interpretation of supraspan memory tasks (Jones et al., 2005). Interestingly, in 1996, Nettelbeck and colleagues had already stated that the first recall and total learning were actually statistically uncorrelated and that, remarkably, the first was more associated with processing speed.

The concept of forgetting is widely present in learning studies, the first representing the opposite of the latter (Davis et al., 2003; Grenfell-Essam et al., 2017). In the present work, we were interested in analysing savings and retention patterns to better understand the memory capacity across the different educational groups. We verified that, although all groups decreased the number of words recalled with time, there are no differences in savings and retention. These results are inconsistent with our third hypothesis that predicted that the less educated groups would present a weaker retention.

The serial position effect has been extensively studied in clinical groups, especially in MCI and AD patients, with significant differences found in recall of primacy and recency words among these groups (Cunha et al., 2012; Howieson et al., 2011; Martín et al., 2013; Orru et al., 2009) but not in healthy samples.

When exploring deeply the learning over trials, we also analysed serial position. Looking at the first trial, all groups showed serial position effect: a "U" shaped curve that is consistently found in literature and a classic representation of better recall of the primacy and recency portions of a wordlist (Capitani et al., 1992). In all educational groups the primacy positioned words and the recency positioned words were better recalled than the middle ones.

A linear regression showed that education does not seem to impact recall of middle words from a wordlist. In other studies, the lack of associations in serial position has been attributed to ceiling effects in recall. For example, Griffin and collaborators (2017) found a ceiling effect in the primacy portion of their wordlist with both age groups under analysis, presenting a magnified recall of that list portion. Nevertheless, that does not seem to be the case in the present work, considering that all groups show a low recall of middle words. One might argue that the opposite could have happened – a floor effect on the recall of middle words can be seen. This could be due to the fact that middle words are more susceptible to interference from other parts of the list (Ebert & Anderson, 2009).

Nonetheless, to our knowledge, there are no studies referring this effect, especially regarding educational level.

As previously mentioned, we were particularly interested in the first and last trials of the learning phase for the analysis of serial position. We found that the less educated groups (group 1 and 2) significantly presented more difficulty in the recall of primacy words in the first trial when compared with the highest educated group. Similarly, the less educated group (group 1) recalled significantly less primacy words than group 4 in the last learning trial. These results are consistent with our initial prediction that there would be group differences in the recall of the words positioned at the beginning of the list, putting the most educated ones in advantage. Nevertheless, in the last learning trial, these differences were also found in the recency portion the wordlist, which was not expected.

During list acquisition tasks, the primacy effect seems to be mostly related with the possibility for rehearsal while recency words do not have such opportunity. Participants from the middle education group (group 2) seemed to have benefited from practice, since a similar performance to groups 3 and 4 was achieved in the last learning trial. The differences in recall of recency, on the contrary, seem to have changed importantly from the first to the last learning opportunity in the less educated group (group 1).

Nevertheless, the highest educated group presented significantly elevated primacy and recency in trials 1 and 4 with the exception of recency in the first trial. Accordingly, more years of education seem to provide easier transfer of information to long-term stores associated with primacy effect as well as facilitated access to transitory short-term stores mostly related with immediate tasks and, thus, recency effect. These results contribute to previous research describing that higher level of education is closely related with overall better performance in cognitive tasks (Lezak, Howieson, Bigler, & Tranel, 2012) and that recency might be a differentiating factor between these groups.

In the clinical context, results in this area were important to improve the detection of mild AD (Buschke, et al., 2006) and predict conversion from MCI to AD (Egli et al., 2014). Thus, understanding serial recall in healthy aging could be the starting point to study the possible predictive weight of memory decline.

Limitations and future work

The present work presented itself to be a challenge when attempting to find balanced education groups. Even though we were able to find a good sample size, the groups could have been more balanced, with special emphasis in group 3 that had less individuals than the remaining groups. In future work, it would be appropriate to have all groups as balanced as possible.

Another limitation of the current project is the presentation of the wordlist. The Cognitive Function Dementia Test Set is computerized and, accordingly, the AWLT wordlist is a pre-recorded sound track presented to the participants. In some cases, it was difficult to clearly hear or understand the words. Because there was no possibility of adjusting the presentation of the list, and we were constrained by the maximum volume of the computer, some participants misunderstood some of the words and, accordingly, persistently recalled the similar/sound-alike word.

According to our results, there seems to be no difference between groups in the middle portion of the wordlist, with all of them performing poorly. A valuable option for future work would be to have a separate cohort presented with a different list of similar characteristics, enabling the comparison between wordlists.

Most studies of serial recall in healthy studies seem to focus on aging. Due to differences on sample size, inclusion and exclusion criteria and the characteristics of the wordlist used, the results of these studies are inconsistent. Accordingly, replication of current results in a different wordlist test would be most valuable, as well as an in-depth analysis integrating at least both sociodemographic characteristics and younger subjects, for a clearer description of serial position patterns in healthy subjects.

Future work could also explore serial recall of education groups in delayed trials to analyse patterns of serial effect in consolidation and recognition. It is described that recency words are more difficult to transfer to long-term memory stores and, accordingly, are not as recalled in delayed recall trials (Craik, 1970). This theory was also proven by Carlesimo, Sabbadini, Fadda, and Caltagirone, (1995) and later reproduced by Griffin and collaborator (2017) with their work with age groups, as well as by Talmi and collegues (2005) in their work with patterns of cerebral activation (functional Magnetic Resonance Imaging). It would be interesting to see if such results are found in different education groups.

Learning patterns and serial position have been a consistent topic of research through the years. More recently, patterns found in clinical groups have proven to be valuable for both research and clinical settings. Nonetheless, the investment in healthy groups is not as consistent. Accordingly, more research should be put into healthy groups, not only to understand their learning patterns, but also to be able to develop better and more robust learning theories as well as a better background for extrapolating into other areas such as clinical or neuroimaging. This would potentially lead to a more detailed study of aging and better predictive models/markers of cognitive decline.

CONCLUSION

The present work intended to analyse learning and serial position effect of healthy subjects with different educational level groups when presented with a free recall wordlist test.

We found that lower educated groups recall less words in all learning and delayed recall trials when compared with the highest educated group (group 4). This difference seems to be particularly clear in the first learning trial and in the short-term delayed recall trial. Despite these differences, all groups presented a similar learning rate with identical learning curves. None of the groups showed significant differences in savings and retention of the acquired information.

Looking into the serial position differences, all educational groups presented the classic "U" shaped serial position effect, that is in accordance to previous literature.

Primacy and recency presented interference of education level. In particular, there was significant differences between groups in primacy in the first learning trial and in primacy and recency in the last learning trial. The differences are most evident in the first trial's primacy and the last learning trial's recency. These results show that, in initial recall, the primacy portion of a wordlist seems to be the most impacted by the level of education, also in agreement with previous research. On the other hand, the differences found in the total amount of words in the final learning trial seem to be more influenced by the recency part of the wordlist.

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