



CATÓLICA
INSTITUTO DE CIÊNCIAS DA SAÚDE

LISBOA · PORTO · VISEU

WHERE DID I LEAVE MY GLASSES?
THE RELATIONSHIP BETWEEN SEMANTIC AND EPISODIC
MEMORY IN HEALTHY AGING

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

Por
Ana Luísa Nogueira Barros Almeida

Lisboa, 2019



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Sob a orientação da Professora Doutora Filipa Ribeiro e da Professora
Doutora Ana Luísa Raposo

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Abstract

Extensive research has described the distinction between semantic memory and episodic memory (e.g., Tulving, 1972). Despite the neurocognitive dissociation between these two memory systems, they often interact. Several studies indicate that semantic knowledge facilitates the retrieval of episodic memories in both young adults and amnesic patients. A well-documented finding is the semantic congruency effect wherein participants display better episodic memory for information that is compatible, rather than incompatible, with their pre-existing semantic knowledge. However, there are divergent results concerning the semantic congruency effect on older adults' episodic memory, and whether that same facilitation is observed is still an open question. Taking this into account, the present study explored the role of semantic memory in the retrieval of episodic memories in healthy older adults in relation to young adults. Particularly, we sought to investigate if and how the congruency between new information to be memorized and previous semantic knowledge enhances episodic memory. For this purpose, we tested item and associative memory (manipulating the congruency of both target objects and distractors) using a recognition memory paradigm with object-scene pairs. The results showed that older adults had worse episodic memory performance than young adults, both in item memory and associative memory. Also, a semantic congruency effect was found in both groups in the item memory task. In the associative memory task, the two groups performed better when the target object was congruent than incongruent and had worse performance for congruent distractors than incongruent ones. Still, older adults benefited more than young adults when the target object was congruent with the scene than when it was incongruent and, on the other hand, were more impaired than young adults when the distractor was congruent than incongruent. Therefore, we suggest that older adults' tendency to choose congruent relationships corroborates the importance of semantic schema and its inflexibility in aging.

Keywords: Episodic memory, Semantic memory, Semantic congruency, Aging

Resumo

A investigação tem reportado a distinção entre memória semântica e memória episódica (e.g., Tulving, 1972). Apesar da dissociação neurocognitiva entre estes dois sistemas de memória, eles interagem frequentemente. Vários estudos indicam que o conhecimento semântico facilita a recuperação de memórias episódicas tanto em jovens adultos como em pacientes amnésicos. Um resultado bem documentado refere-se ao efeito de congruência semântica em que os participantes mostram melhor memória episódica para informação compatível com o seu conhecimento prévio do que para informação incompatível. No entanto, existem resultados divergentes sobre o efeito de congruência semântica na memória episódica dos idosos, sendo que se mantém em aberto a pergunta sobre se essa facilitação é de facto observada ou não nesta população. Tendo isso em consideração, o presente estudo explorou o papel da memória semântica na recuperação de memórias episódicas em idosos saudáveis relativamente a jovens adultos. Em particular, procurámos investigar se e como a congruência entre a nova informação a memorizar e o conhecimento semântico prévio potencia a memória episódica. Com este objetivo, testámos a memória de item e a memória associativa (manipulando a congruência de objetos-alvo e distratores) usando um paradigma de memória de reconhecimento com pares objeto-local. Os resultados mostraram que os idosos apresentaram um desempenho de memória episódica pior que os jovens adultos, tanto na memória de item como na memória associativa. Além disso, encontrou-se um efeito de congruência semântica nos dois grupos na tarefa de memória do item. Na tarefa de memória associativa, os dois grupos tiveram melhor desempenho quando o objeto-alvo era congruente do que incongruente e apresentaram pior desempenho para os distratores congruentes do que para os incongruentes. Ainda assim, os idosos beneficiaram mais do que os jovens quando o objeto-alvo era congruente com o local do que quando era incongruente e, por outro lado, foram mais prejudicados do que os jovens quando o distrator era congruente do que incongruente. Posto isto, sugerimos que a tendência dos idosos para escolher relações congruentes corrobora a importância de esquema semântico e a sua inflexibilidade no envelhecimento.

Palavras-Chave: Memória episódica, Memória semântica, Congruência semântica, Envelhecimento

À minha Avó

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“I took a deep breath and listened to the old brag of my heart: I am, I am, I am.”

Sylvia Plath

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Introduction

One of the most common complaints in aging is memory failure. Interestingly, while episodic memory (i.e., the ability to recall specific past events; e.g., I left my glasses on the dining room table) shows a significant decline with age (even in healthy aging), semantic memory (i.e., general knowledge about the world; e.g., glasses are used to correct faulty vision) remains intact (e.g., Nyberg, Lövdén, Riklund, Lindenberger & Bäckman, 2012). Behavioural studies with healthy young participants (Craik & Lockhart, 1972) and with amnesic patients, along with neuroimaging evidence (Staresina, Gray & Davachi, 2009) have shown that prior semantic knowledge can facilitate episodic retrieval of new information. For example, participants remember events that are semantically congruent better than events consisting of incongruent elements.

This study aims to explore the role of semantic memory in the retrieval of episodic memories in healthy older adults, comparing them with a group of younger adults. In particular, we intend to examine the influence of semantic congruency on episodic retrieval by inspecting the accuracy in a recognition memory task for objects that are associated with a congruent semantic context (e.g., glasses-living room) vs. incongruent (e.g., glasses-balcony). This study will help understanding how people dynamically employ prior knowledge in episodic learning. Addressing this question in the elderly may be an important step towards coping with the significant memory decline in this population.

Literature review

Distinction between episodic memory and semantic memory

Memory is a fundamental human capacity that enables us, among other things, to access facts, to recall past experiences, to acquire new knowledge, to foresee the future, to tell stories and to know who we are. Extensive research has described the different memory systems, namely the distinction between semantic memory and episodic memory (e.g., Tulving, 1972). Semantic memory corresponds to our general knowledge of the world around us without specific spatiotemporal information (e.g., knowing that a pack is a group of wolves). On the other hand, episodic memory refers to the recollection of

personal episodes or specific events associated with a given spatiotemporal context (e.g., knowing that I saw a wolf yesterday at the zoo). This distinction has clear heuristic value and is broadly accepted in the field of psychology (Greenberg & Verfaellie, 2010; Tulving, 2002).

Functional imaging studies in healthy adults provide evidence that semantic memory and episodic memory recruit different brain structures and neural networks, although they show some overlap in regions such as the prefrontal cortex (Barba, Parlato, Jobert, Samson & Pappata, 1998; Cabeza & Nyberg, 2000; Wiggs, Weisberg & Martin, 1999). Episodic memory typically relies on the medial temporal lobe and, in particular, the hippocampus (Bayley, Hopkins & Squire, 2006; Squire, Stark, & Clark, 2004; Vargha-Khadem et al., 1997), which encodes and stores new information, as well as the context associated with this learning, quickly. The functioning of semantic memory involves the lateral temporal lobe (Martin & Chao, 2001; Patterson, Nestor & Rogers, 2007), particularly its most anterior portion (Lambon Ralph, Ehsan, Baker & Rogers, 2012; Pobric, Jefferies & Lambon Ralph, 2007). The neuropsychological literature has also made key contributions to demonstrate the independence of the two memory systems. Semantic dementia is a progressive neurodegenerative disorder characterized by the loss of semantic knowledge, but patients retain the capacity to recall events from episodic memory (Irish et al., 2016). Conversely, patients with developmental amnesia resulting from bilateral hippocampal atrophy typically show preserved semantic memory, despite severe impairments in episodic memory (Elward & Vargha-Khadem, 2018).

In short, semantic and episodic memory are independent systems: they are associated with distinct cognitive functions, have different neural bases and are differentially affected by neurological lesions.

How semantic knowledge influences episodic memory

Despite the neurocognitive dissociation between semantic and episodic memory, the two memory systems often interact. Craik and Lockhart (1972) have shown that semantically encoded items (e.g., deciding if the word is an animal) are better remembered than perceptually encoded items (e.g., deciding if the word is written in capital letters), suggesting that memory trace strength is a function of the level of semantic involvement. Their influential approach, the levels of processing framework, allows to

explain how the memory of a new event (episodic memory) is associated with pre-existing semantic knowledge (semantic memory), thus establishing relationships between the two memory systems (Zion-Golombic, Kutas & Bentin, 2010; Kan, Alexander & Verfaellie, 2009; Staresina et al., 2009). In the same way, Schulman (1974) and Craik and Tulving (1975) proposed that semantically congruent events (e.g., coat-yellow) are better remembered than semantically incongruent events (e.g., elephant-yellow) since they promote semantic elaboration, given that its elements form a unit with a pre-existing relationship, making the memory trace more accessible. So, at the time of encoding, prior knowledge is used to interpret the stimulus and, in retrieval, information from the new event that has been integrated into that knowledge calls upon semantic memory to reconstruct the initial encoding (Craik & Tulving, 1975).

Some neuroimaging studies have revealed the neural substrates of different levels of processing. Both Wagner and colleagues (1998) and Gabrieli and colleagues (1996) who used functional magnetic resonance imaging (fMRI), as well as Tulving, Kapur, Craik, Moscovitch and Houle (1994) who made use of positron emission tomography (PET), reported greater activation in the left prefrontal cortex during performance of a semantic processing task (e.g., deciding if a word is abstract or concrete) compared to a perceptual processing task (e.g., deciding if a word is printed in upper- or lowercase letters). Moreover, they found that the magnitude of activation in this brain region is associated with successful memory formation, predicting whether a specific event would be later remembered or forgotten, i.e., subsequent memory effect (Wagner et al., 1998).

Other studies have provided evidence that event congruency enhances subsequent memory performance through semantic elaboration. Staresina and colleagues (2009) investigated the congruency effect and its underlying brain mechanisms using behavioural and neuroimaging measures. These authors proposed that if the episodic memory effect associated with event congruency is driven by semantic elaboration, then congruent events should activate regions typically involved in this elaboration (namely, the left inferior prefrontal cortex), as opposed to what occurs with incongruous events. Furthermore, they inferred that a better episodic memory for congruent events should be accompanied by a greater recall of the contextual details of the moment the event was encoded (e.g., recall of the specific task in which a certain word was found). Results confirmed that event congruency (e.g., yellow-balloon) was associated with superior

recall of the contextual details of the event, as well as greater activation of the prefrontal cortex compared with incongruent events (e.g., red-elephant). Taken together, these results support that event congruency promotes successful memory formation through semantic elaboration, since relational bindings are established between the new information received and semantic knowledge (Staresina et al., 2009).

In investigating how brain activity is altered by semantic congruency, van Kesteren and colleagues (2013) adopted Bartlett's well-known notion of schema (1932), and proposed it as a network of tightly interconnected cortical representations that, when activated, influences the processing of new information that is related to pre-existing knowledge. In this study, participants saw object-scene pairs (e.g., toothbrush-bathroom) and had to rate the degree of congruency of each pair while being scanned. After 24 hours they performed an item recognition test in which they were asked to discriminate old objects from new ones. For objects judged as old, subjects additionally performed an associative recognition test, having to choose which of three alternative words corresponded to the scene previously paired with that object. The results showed that item recognition and associative recognition presented memory advantage for congruent information. The interaction between subsequent memory and subjective congruency of new information with prior knowledge revealed an increased activation of the medial prefrontal cortex and cingulate regions when congruent associations were being encoded, while activation of the medial temporal lobe during encoding was greater for incongruent associations (e.g., toothbrush-kitchen). This evidence supports the SLIMM (Schema-Linked Interactions between Medial prefrontal and Medial temporal regions) framework, which suggests that the medial prefrontal cortex and medial temporal lobe interaction during encoding and their respective contribution is controlled by the congruency of the information to be remembered and an existing schema.

A particularly relevant question concerns whether the same semantic enhancement effect upon episodic memory occurs in patients with amnesia. In organic amnesia syndrome, patients tend to have preserved intelligence and working memory, while exhibiting an impaired ability to recall and recognize recently learned information even after just a few seconds (anterograde amnesia) or an inability to recall and recognize personal episodes that occurred prior to the lesion (retrograde amnesia) (Brizzolara, Casalini, Montanaro & Posteraro, 2003; Mayes & Montaldi, 2001; Mayes & Downes,

1997). Most of these amnesia cases tend to be quite asymmetrical in respect to the detriment of episodic memory in relation to semantic memory which tends to be more preserved (Kopelman, Stanhope & Kingsley, 1999; Levine et al., 1998; Schmolck, Kensinger, Corkin & Squire, 2002; Vargha-Khadem et al., 1997; Vargha-Khadem et al., 2003; Viskontas, McAndrews & Moscovitch, 2002; although see Spiers, Maguire & Burgess, 2001 for cases of amnesic patients who also have marked semantic memory losses). The fact that episodic memory is compromised, and semantic knowledge preserved has raised the question of whether amnesic patients can learn new semantic information even though they cannot remember the moment they learned it (Skotko et al., 2004; Squire et al., 2004; Tulving, 2002). Indeed, several experiments have shown that amnesic patients can acquire new semantic information (e.g., Gardiner, Brandt, Baddeley, Vargha-Kadem & Mishkin, 2008; Hamann & Squire 1995; Hayman, MacDonald & Tulving, 1993; Kitchener, Hodges & McCarthy, 1998; O’Kane, Kensinger & Corkin, 2004; Stark, Stark & Gordon, 2005; Van der Linden, Bredart, Depoorter & Coyette, 1996; Van der Linden et al., 2001; Verfaellie, Koseff & Alexander, 2000; Westmacott & Moscovitch 2001; Tulving, Hayman & McDonald, 1991), and the role of pre-existing knowledge in determining the type of information they can acquire is crucial (Brizzolara et al., 2003). In fact, new semantic knowledge becomes meaningful if it relates to domains that patients already knew or if the new facts are consistent with pre-existing concepts. This means that they can acquire new semantic information if it is anchored in previously established mental representations (Skotko et al., 2004; Hayman et al., 1993; Tulving et al., 1991; Van der Linden et al., 1996).

More recent investigations have tried to ascertain whether this line of thought applies to episodic memory. Specifically, Kan and colleagues (2009) investigated the role of prior semantic knowledge in episodic learning in amnesic patients, specifically in a subset of patients with lesions restricted to the medial temporal lobe (with the semantic system intact) and in a subgroup of amnesic patients with medial and lateral temporal lesions (i.e., with the semantic system affected). Subjects studied prices of grocery and household items that were either congruent with their prior knowledge (e.g., \$3.85 for a gallon of milk) or incongruent (e.g., \$7.59 for a dozen eggs). Then, participants performed a forced-choice recognition test in which they were asked to select the studied price from a set of four prices that included three foils. The results showed that amnesic patients with

strictly medial lesions performed better on the episodic memory test for semantically congruent items than patients with medial and lateral temporal lesions, i.e., only the former group benefited from the congruency effect. This suggests that the integrity of the lateral temporal lobe is indispensable for semantic memory to sustain episodic memory.

These findings support the existence of a range of interdependencies between semantic and episodic memory and have implications for the rehabilitation of patients with episodic memory disorders. In other words, the severity of the episodic deficit and the integrity of the pre-morbid semantic knowledge, as well as the type of information that can be integrated with pre-existing knowledge can determine the success of rehabilitation programs (Greenberg & Verfaellie, 2010).

Semantic and episodic memory abilities in healthy aging

Several studies have revealed marked differences between semantic memory and episodic memory capabilities in healthy aging. Specifically, the results show that age is not related to semantic memory performance, but it is a significant predictor of episodic memory performance (Craik, 1994; Nyberg, Backman, Erngrund, Olofsson, & Nilsson, 1996; Nyberg et al., 2012; Shing et al., 2010). Thus, older adults exhibit difficulties in recalling past experiences, although they have an intact or even better semantic knowledge than young adults, namely in vocabulary tests (Hedden & Gabriele, 2004; Park & Reuter-Lorenz, 2009; Spaniol, Madden, & Voss, 2006; Verhaeghen, 2003).

Despite the superior episodic memory for young than older adults, this age difference in performance depends on the specific type of memory that is tested (Old & Naveh-Benjamin, 2008). Item memory refers to the ability of recalling or recognizing previously presented items, such as single words, objects or faces. Associative memory is defined as the ability to learn and remember the relationship between distinct items, such as associating a name with a face or an object with a context. Associative memory requires the formation of a new episode through the binding of features or the integration of events (Castel & Craik, 2003). Chalfonte and Johnson (1996) tested these types of memory by presenting participants with several coloured objects located within an array and instructed them to study particular features (e.g., colour) or to study the features together (e.g., object plus its colour). The results showed that recognition memory for objects and for colours in older adults was equivalent to that of young adults. However,

older adults were less able in binding the two features together. The authors suggested that in older ages the ability to bind information into complex events may be impaired, but not memory for specific features. This means that aging differentially affects memory for single units (i.e., item memory) and memory for associations among those units (i.e., associative memory) (Old & Naveh-Benjamin, 2008). Naveh-Benjamin (2000) extended these results by testing the associative deficit hypothesis (ADH) which states that an important contributor to older adults' deficits in episodic memory is their decreased ability to encode and retrieve links among single units of information. The author carried out four experiments in which young and older adults studied word-nonword pairs, word-word pairs, or words written with different fonts. Older adults demonstrated a significantly larger deficit in recognition of associative information (i.e., both inter-item and intra-item relationships) than for single item components (i.e., each word). The authors concluded that a major cause of older adults' episodic memory decline is their difficulty in merging different units of an episode into a cohesive unit.

In addition to binding, executive control processes, notably inhibition, also play a critical role in memory encoding and retrieval, particularly in associative tasks. Inhibitory control processes are key for focusing attention on information that is relevant and avoiding highly learned but currently wrong response trends (Rey-Mermet & Gade, 2017). Inhibition which is often defined as resistance to interference from stimuli that are irrelevant decreases throughout aging. For example, Connelly, Hasher and Zacks (1991) asked participants to read a series of brief passages that may or may not have interspersed distracting material. Participants were instructed to ignore the distractors and read only the text in italics. After reading each passage subjects had to answer a multiple-choice test. Additionally, they were given a surprise test to recall any distractor words about the seventh story. The results showed that both older and younger adults were hindered when distracting material was present compared to a non-distractor condition. However, the interference to reading time from distraction was substantially greater for older than for younger participants, indicating an age-related effect for reading with distractors. The authors also conducted a second experiment, similar to the first, in which they manipulated the type of distracting material which could be meaningless, meaningful but unrelated to the text or meaningful but text related. Semantically meaningful distracting information (i.e., text-related and text-unrelated conditions) was more disruptive to both

younger and older adults than meaningless material. Importantly, when distracting material was related to the target text, older adults had a harder time ignoring the distracting information, as revealed by longer reading times than when distracting material had no meaning to the target text. Yet, this pattern was not seen in younger adults. This suggests that information related to the text might cause greater attentiveness for older adults than for younger adults. Thus, the mechanism responsible for the greater disruption presented by older adults may be the age-related decline in the ability to inhibit task irrelevant information occurring during the selection of task relevant information.

Overall, the behavioral studies demonstrating a decrease in binding and inhibitory abilities in the elderly are in line with neuroimaging data showing that the decline in episodic memory along aging is accompanied by a decrease in white matter integrity, especially in the frontal areas, critical in inhibitory control (Park & Reuter-Lorenz, 2009). In addition, a reduction in the volume of brain structures important in episodic memory has also been reported, including the prefrontal cortex (Raz et al., 2004; Van Petten et al., 2004), as well as the medial temporal lobe (Persson et al., 2006), and the hippocampus (O'Shea, Cohen, Porges, Nissim & Woods, 2016; Raz et al., 2005; Rajah, Kromas, Han, & Pruessner, 2010), regions that are important for building associations across stimulus (Borders, Aly, Parks, & Yonelinas, 2017).

Older adults do not show reduced memory on all associative memory tasks, since the meaningfulness of the information to be learned and its consistency with prior knowledge can influence their performance (Amer, Giovanello, Grady & Hasher, 2018). However, the role that intact semantic knowledge can play in slowing the decline of episodic memory in healthy aging is still poorly understood.

Indeed, there are not many studies that have directly analysed the effect of semantic congruency at older ages, but some conclusions can be drawn. For instance, Castel (2005) investigated how arbitrary and more meaningful relations influence younger and older adults' performances. Participants studied pictures of grocery items, each one paired with a realistic price that was congruent with the market value of that item (e.g., butter \$2.99) or an inflated price that was incongruent with the market value (e.g., soup \$14.39), and afterwards they tried to recall the price for each item. The results showed that realistic prices were better recalled than inflated prices and that there was no age difference in memory for the realistic (i.e., congruent) prices, but for the inflated (i.e., incongruent)

younger adults outperformed older adults. Similarly, Amer and colleagues (2018), using a paradigm adapted from Castel (2005) showed that older adults had an associative memory performance as good as younger adults when the association item-price was based on semantic knowledge (as opposed to unrealistic prices).

Naveh-Benjamin, Hussain, Guez, and Bar-On (2003) tested young and older adults' memory using pairs of words that were semantically related or unrelated. The authors found that older adults demonstrated a lower associative deficit for semantically related word pairs than for unrelated word pairs. They also examined performance for pairs of pictures in order to extend the ADH to materials other than verbal ones. In this experiment older adults showed a larger deficit in the associative recognition test relative to the item test, and they performed worse than young adults in recognition of associative information, confirming the ADH. Likewise, Smith, Park, Earles, Shaw, and Whitinga (1998) presented participants with pairs of pictures which were either related to each other or not. The results showed that older adults memory benefited from the related pairs of pictures just like younger adults, in contrast to what occurred with unrelated pairs where younger adults had a better performance. Overall, it seems that preserved semantic knowledge can sometimes compensate for deficits in older adults' episodic memory when it integrates information that is consistent with it, allowing older adults to reach the same level as young adults. However, a heavy reliance on prior knowledge may impair older adults' memory, as when information to be remembered is inconsistent with their knowledge (Umanath and Marsh, 2014).

Nonetheless, resorting to semantic knowledge does not always benefit older adults more than young adults. For example, Gutchess and Park (2009) compared the effects of aging on recognition for complex pictures with a central object presented against a background that could be related (e.g., cow-farm) or unrelated (e.g., cow-laundry room). They found that the semantically meaningful pictures resulted in an equivalent memory in young and older adults. Surprisingly, older adults remembered unrelated pictures just as well as young adults, demonstrating that memory can also be age-invariant for unusual relationships. The authors propose that memory for complex pictures (with rich associations between the different elements) does not rely on prior knowledge and that associative memory for complex pictures may differ from memory for inter-item associations, which seem to be more affected by aging. Arbuckle, Vanderleek, Harsany

and Lapidus (1990) tested young and older adults that were either music experts or had no formal training in music. Participants read four passages about music (e.g., jazz) and dogs (e.g., poodles) and after reading each passage they responded to a question test. The results revealed that music experts showed better memory for the music passages than participants without music training, but this finding did not extend to the dog passages. This finding supports the idea that availability of a relevant schema, in this case expertise, facilitates information retrieval. Moreover, music experts were benefited to the same degree when they remembered information about music regardless of age group.

As previously mentioned, semantic knowledge (namely, semantic congruency) facilitates the retrieval of episodic memories in both young adults and amnesic patients. Regarding older adults' episodic memory, there are divergent results concerning the semantic congruency effect. Whether that same facilitation is observed in healthy older adults is still an open question.

The present research

The aim of the present study is to explore the role of semantic memory in the retrieval of episodic memories in healthy older adults in relation to young adults. Particularly, we intend to investigate if and how the congruency between new information to be memorized and previous semantic knowledge enhances episodic memory.

To this end a recognition memory paradigm was used, which included an encoding phase and retrieval phase. The semantic congruency variable was manipulated in the encoding phase, since according to the literature review it promotes semantic elaboration (e.g., Craik & Tulving, 1975). In particular, it has been shown that semantic congruency leads to better episodic memory retrieval, not only in healthy adults but also in amnesic patients (e.g., Kan et al., 2009; Staresina et al., 2009). Thus, we aim to study if the same effects are observed in older adults. For this purpose, coloured photographs of objects and scenes were chosen from a database of object-scene pairs that includes several measures of the images, including the degree of semantic congruency between the objects and scenes. In the encoding phase, object-scene pairs that were congruent (e.g., crown-palace) or incongruent with semantic knowledge (e.g., comb-restaurant) were presented to the participants.

The retrieval phase consisted of an item memory task and an associative memory task. The first is a recognition task in which objects presented during encoding and new ones are presented, and participants have to decide whether the items are old or new. This task allows to evaluate the memory of items studied during the encoding phase. The second is also a recognition task, in which participants see a previously presented scene and have to decide which of two old objects (the target and a distractor) had been paired with that particular scene. Both the target object and the distractor object can have a congruent or incongruent relationship with the scene. This task allows to evaluate memory for item-context associations established in the encoding phase, and thus test how binding abilities (associating the object and the scene) and inhibitory control (avoiding the interference of the distractor objects) affects associative memory in the two age groups.

Based on the literature revised here, the following hypotheses regarding recognition memory are suggested:

H_{1a}: No differences are expected between older and young adults in item memory, since this task does not tap in a great extent into inhibitory control or binding of features.

H_{1b}: A congruency effect across groups is expected, where objects coming from congruent relationships are expected to be better remembered than those coming from incongruous relationships. In general, items with congruent relationships are better encoded and retrieved than items with incongruent relationships, as demonstrated by an extensive literature on the influence of semantic schemas on episodic memory.

H_{2a}: In regard to associative memory, differences between the two groups are expected. Associative memory is not only more demanding in establishing new associations than item memory, but also requires more executive control processes to establish these relationships or inhibit relationships that are not correct. Therefore, we anticipate lower associative memory performance for older adults compared to young adults due to deficits in these components.

H_{2b}: When the target is congruent with the scene, both groups are expected to perform better than when the target is incongruent; and when the distractor is congruent with the scene, performance is expected to be worse than when it is incongruent. These hypotheses are based on the above-mentioned proposal that episodic performance is influenced by previous schemas. Thus, when the target is congruent with prior schemas

there should be a facilitation in associative memory. Conversely, when the distractor object entails a semantic relationship with the scene, associative memory performance should be hindered.

H_{2c}: Older adults' memory is expected to benefit more from a congruent relationship between the scene and the target object (relative to an incongruent relation) than young adults' memory; in a similar vein, we predict that older adults will have a poorer performance than young adults when the distractor is congruent than when it is incongruent. When the target object is congruent with the scene, older people should rely more on semantic knowledge and this helps their performance, but when the target is incongruent, they can no longer rely on that knowledge and therefore performance worsens in that condition. This semantic congruency benefit should then be greater in older than younger adults. Regarding the distractor, as episodic memory is worse in older adults, they presumably rely on semantic knowledge in a greater extent and are less able to inhibit the distractor's congruent relationship with the scene, as compared to the younger group. Thus, the semantic hindering effect should be larger in the older group.

Along with the episodic memory task, some neuropsychological tests were applied to analyse individual differences between participants and correlate their performance with measures of the main memory task. To complement the evaluation of episodic verbal memory and semantic integrity we used the Logical Memory subtest of the Wechsler Memory Scale-III and the Camel and Cactus Test, respectively. The Standard Raven's Matrices evaluated abstraction ability and a Go/No-Go task was used to measure inhibitory control ability. Finally, the Montreal Cognitive Assessment and the Geriatric Depression Scale allowed to ensure the general cognitive integrity of the older adults, as well as the absence of depressive symptoms.

Method

Participants

Data were collected from 37 young adults and 42 older adults. Participants had to meet the following inclusion criteria: (a) be between the ages of 24 and 30 for young adults and 60 and 75 for older adults; (b) have a level of education equal to or higher than

12th grade; (c) no self-reported psychiatric disorders (e.g., major depression); (d) no neurological disorders with cognitive effects (e.g., stroke, epilepsy, multiple sclerosis); (e) no systemic diseases with impact on the nervous system and cognition (e.g., lupus, uncontrolled diabetes and hypertension); (f) no substance abuse; (g) have normal or corrected to normal eyesight; and (h) be a native speaker of European Portuguese. Participants were excluded if there was: (a) evidence of mental deterioration confirmed by a score of 2 or more standard deviations below the mean in the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005; Simões et al., 2008); and (b) evidence of depressive symptomatology evaluated by the Geriatric Depression Scale₁₅ (GDS₁₅; Sheikh & Yesavage, 1986). Four older adults were excluded because one did not meet the education requirement, two scored below the cut-off points in the MoCA, and the other failed to complete the task correctly (presented too many non-answers in one of the retrieval blocks). Therefore, thirty-seven healthy young adults (11 male; $M = 26.08$ years, $SD = 1.79$) and 38 healthy older adults (14 male; $M = 66.66$ years, $SD = 4.52$; MoCA: $M = 25.76$, $SD = 1.76$; GDS₁₅: $M = 1.24$, $SD = 1.46$) were included in this study. Young adults were recruited from various universities in Lisbon, and older adults were mainly recruited from Senior Universities from the Lisbon Metropolitan Area. All participated voluntarily in the experiment after informed consent (Appendix 1). The study was approved by the Scientific Committee of the Catholic University of Portugal and by the Ethics Committee of the Faculty of Psychology of the University of Lisbon.

Materials

The study consisted of five tasks. An episodic memory task and four complementary tasks: the Logical Memory subtest of the Wechsler Memory Scale-III (Wechsler, 2008); a Go/No-Go task (e.g., Brocki & Bohlin, 2004); the Raven's Standard Progressive Matrices (SPM; Raven, Court, & Raven, 1995); and the Camel and Cactus Test (CCT; Bozeat, Lambon Ralph, Patterson, Garrard & Hodges, 2000). Additionally, the MoCA and the GDS₁₅ were applied to the older adults' group.

For the episodic memory task, we selected 120 coloured photographs of common scenes (i.e., a place) and 240 coloured photographs of common objects from a database of 500 pictures (with no words or faces) obtained from the Internet and extensively pre-tested in a previous study.

The paradigm consisted of a computer-based recognition memory task which included an encoding phase and a retrieval phase. In the encoding phase, 120 pairs of objects and scenes were presented. The relationship between object and context (scene) was manipulated, so that half of the pairs were semantically congruent (e.g., crown-palace), while the other half were semantically incongruent (e.g., comb-restaurant). The retrieval phase comprised two blocks, the first consisted of an item memory task and the second comprised an associative memory task. In the item memory task, 120 objects presented in the encoding phase (i.e., old objects) along with 120 new objects (i.e., not presented at encoding) were used. In the associative memory task, each previously presented scene was displayed along with two old objects, i.e., the target (which had been paired with the scene during encoding) and a distractor (an old object that had been paired with another scene at encoding). The relationship between the scene and the target object was either semantically congruent or incongruent (according to encoding). The relationship between the scene and the distractor object was also manipulated to be congruent or incongruent. As such, there were 4 conditions with 30 trials each: both target and distractor were semantically congruent with the presented scene (CC condition; e.g., stationery store - paper clip, stapler); the target was semantically congruent while the distractor was incongruent (CI condition; e.g., amusement park – popcorn machine, car air freshener); the target was semantically incongruent whereas the distractor was congruent (IC condition; e.g., fire station - pencil, fire extinguisher); both target and distractor were semantically incongruent (II condition; e.g., lake - vacuum cleaner, thermometer).

Overall, objects and scenes across the different conditions were matched for name agreement, familiarity and visual complexity (with $p > .05$ in all cases). Within the 240 object-scene relationships used, the 120 congruent pairs were significantly more related with each other ($M = 4.56$, $SD = .37$) than the 120 incongruent pairs ($M = 1.24$, $SD = .20$) [$t(238) = 86.233$, $p < .001$]. Besides, the target and distractor relationships were controlled accordingly to each of the four conditions in the associative memory task. Namely: for the CC condition, there were no significant differences in the degree of semantic relation between the congruent target-scene pairs ($M = 4.54$, $SD = .37$) and the congruent distractor-scene pairs ($M = 4.62$, $SD = .37$) ($p > .05$); for the CI condition, congruent target-scene pairs ($M = 4.47$, $SD = .39$) were significantly more related than

incongruent distractor-scene pairs ($M = 1.27$, $SD = .21$) [$t(58) = 39.521$, $p < .001$]; for the IC condition, incongruent target-scene pairs ($M = 1.23$, $SD = .21$) were significantly less related than congruent distractor-scene pairs ($M = 4.60$, $SD = .34$) [$t(58) = -46.278$, $p < .001$]; and, for the II condition, there were no significant differences in the semantic relationship between the incongruent target-scene pairs ($M = 1.19$, $SD = .14$) and the incongruent distractor-scene pairs ($M = 1.28$, $SD = .24$) ($p > .05$). All these measurements were taken from the database used.

The episodic memory task was built and presented using the E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Accuracy and response times (in milliseconds) of participants were also recorded with this program.

Regarding complementary tasks, the Logical Memory test (Wechsler, 2008) is used to evaluate immediate and delayed recall ability of verbal material. It consists of two stories, each including 25 items or ideas. However, only the first (Story A) was presented. The Go/No-Go task was designed to assess inhibitory executive function. Andrade (2014) created 100 items, 75 of which Go stimuli and 25 No-Go stimuli, being a replication of Brocki and Bohlin (2004). There were four types of Go stimuli: a square with an X, a square with a diagonal to the right, a square with a diagonal to the left, and a square with a short vertical line in the middle. The No-Go stimulus consisted of an image of a square with a long vertical line in the middle. The Raven's Progressive Matrices consist of 60 visual pattern matching and analogy items grouped into five sets (A to E) of 12 items each (Lezak, Howieson, Bigler & Tranel, 2012) which were used to obtain an index of intellectual capacity. To evaluate semantic memory, the non-verbal version of the CCT was applied, which consists of a target image and four alternative images of coloured photographs of landscapes and objects that have different types of semantic relationships, totaling 64 items (Fonseca, Miranda, Moura, Raposo & Martins, 2016). The MoCA is a screening tool to detect mild cognitive impairment that assesses eight cognitive domains: executive functions; visuospatial abilities; short-term memory; language; attention, concentration, and working memory; and temporal and spatial orientation (Nasreddine et al., 2005). Lastly, the GDS₁₅ is a self-response instrument consisting of 15 items that address the affective and cognitive domains (Simões, Prieto, Pinho, Sobral & Firmino, 2015). Of these 15 questions, 10 indicate presence of depressive symptomatology if the

answer is positive and the remaining indicate depressive symptoms when answered negatively (Sheikh & Yesavage, 1986).

Procedure

The experiment consisted of individual sessions of about 90 minutes and the sequence of task presentation was different for each group of participants, since two additional tasks were applied to the older adults. In this group, the experiment started with the immediate recall of the Logical Memory test, which requires a latency time of 20 minutes, during which only nonverbal tasks were applied (so not to interfere with the verbal stimuli of the test). Thus, they performed the encoding phase of the episodic memory task and the Go/No-Go task before the delayed recall of the Logical Memory. Afterwards, the MoCA and the GDS₁₅ were applied, followed by the retrieval phase of the episodic memory task. Finally, the Raven's Progressive Matrices and the CCT concluded the experimental session. Regarding the young adults' group, the session began with the encoding phase of the episodic memory task, followed by the Raven's Progressive Matrices. After that, they performed the retrieval phase of the memory task, followed by the immediate recall of the Logical Memory test. Then, the Go/No-Go and the CCT were applied, and the delayed recall of the Logical Memory test ended the experiment.

Episodic Memory Paradigm. The main task had both an encoding and retrieval phase. During encoding, participants were shown pairs of coloured photographs, in which a common object appeared next to a place (scene), and they had to indicate whether the object and location were related or not. For half of the participants, the object was displayed on the left side of the screen and the scene on the right side, while for the other half it was the other way around, in a counterbalanced manner. The task started with a training session consisting of 4 trials for the young adults and 8 trials for the older adults (feedback was given only to the older adults), followed by the main experiment that included a total of 120 trials, with a short break after 60 trials. Each trial started with a fixation cross for 500 milliseconds, followed by the presentation of a pair of images for 2000 milliseconds, during which participants had to indicate whether the pair was related or not. The stimuli remained on the screen during this time limit, regardless of the participant's response time. To answer "yes" participants pressed the green key (letter

“o” of the keyboard) with the right index finger and to answer “no” they pressed the red key (letter “p” of the keyboard) with the right middle finger. Between trials, there was an interval of 500 milliseconds with a blank screen (cf. Figure 1). Trials were presented in a random order. It is important to note that participants were not warned that they would need to recall the images ahead.

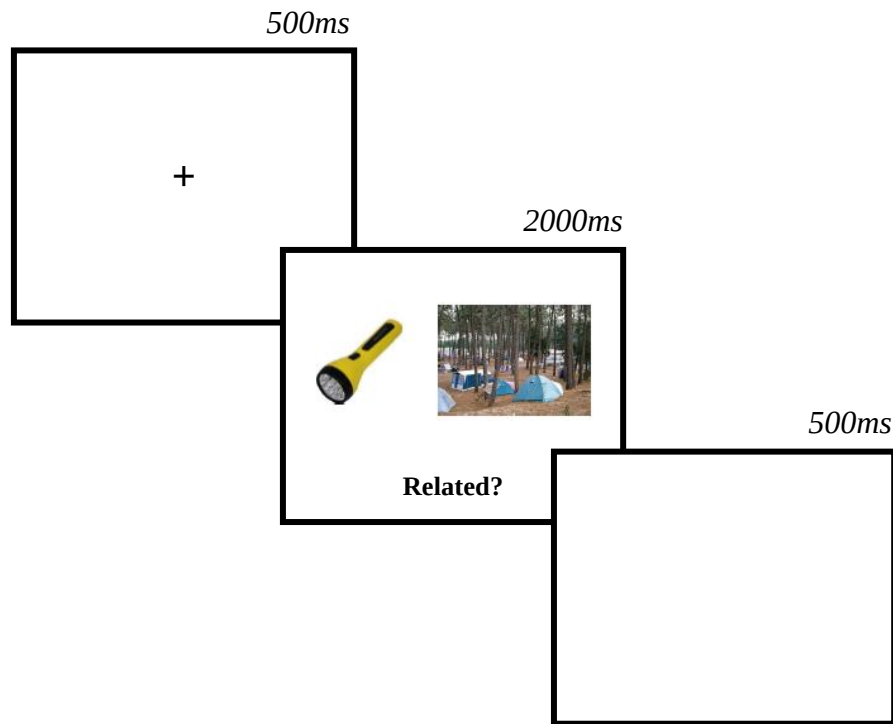


Figure 1. Illustration of a trial from the encoding phase of the memory paradigm.

The retrieval phase started approximately 30 minutes after the encoding task. Item and associative memory were tested in different blocks. In the item memory task, participants were presented with previously seen objects (from the encoding phase) along with new ones and were asked to decide if the item was old (i.e., if it had been previously presented) or not. This task began with a training session consisting of 8 trials for the young adults and 16 trials for the older adults (again feedback was given to the older adults), followed by the main experiment that comprised a total of 240 trials, with two short breaks in between (after every 80 trials). Each trial started with the presentation of a fixation cross for 500 milliseconds, followed by the presentation of an object for 2500 milliseconds during which participants had to decide if the object was old or not. Participants responded “yes” by pressing the green key with the right index finger or “no”

by pressing the red key with the right middle finger. Between trials there was an interval of 500 milliseconds with a blank screen (cf. Figure 2). Trials were presented in a random order.

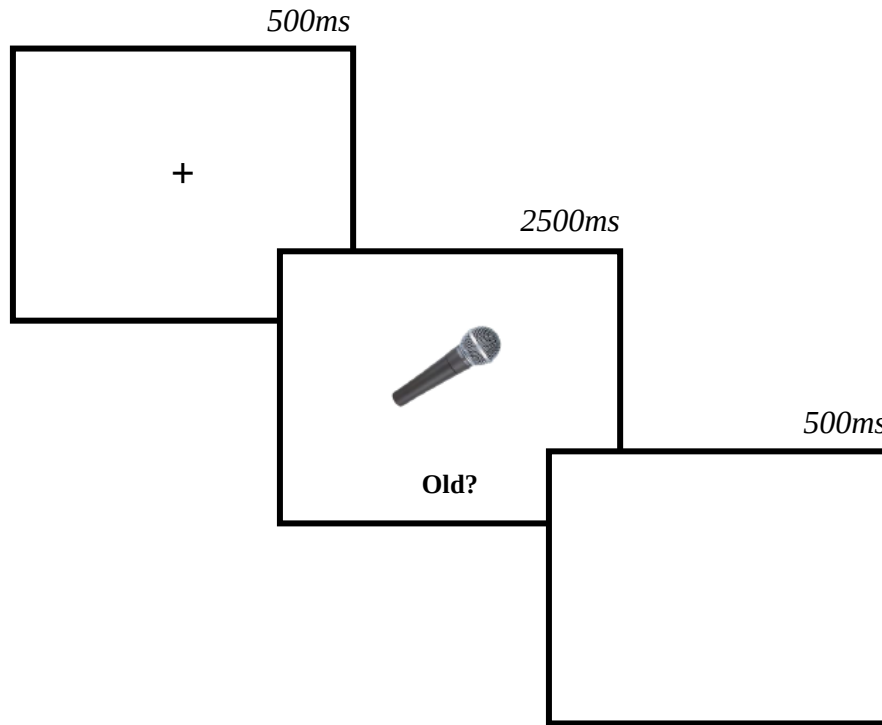


Figure 2. Illustration of a trial from the item recognition block of the memory paradigm.

After the item memory task, participants carried out the associative memory task. Participants saw a scene and two objects (the target and a distractor) from the encoding phase and had to decide which one had appeared earlier with that scene. Both the target and the distractor were either related or unrelated to the scene, so it was emphasized that participants should not respond based on the semantic relationship. The task started with a training session consisting of 4 trials for the young adults and 8 trials for the older adults (feedback was provided to the older adults only), followed by the main experiment consisting of 120 trials, with one short break after 60 trials. Each trial was initiated with a 500ms fixation cross, followed by the presentation of a scene in the upper half of the computer screen for 500ms. Immediately after, two old objects and the question “Associated with which object?” appeared on the screen just below the scene for 3500 milliseconds. During this time, participants had to choose which object had been presented before with the scene. To select the object on the left, they had to press the

green key with the right index finger, while to select the object on the right they pressed the red key with the right middle finger. Between trials a blank screen was presented for 500 milliseconds (cf. Figure 3). Trials were presented in a random order.

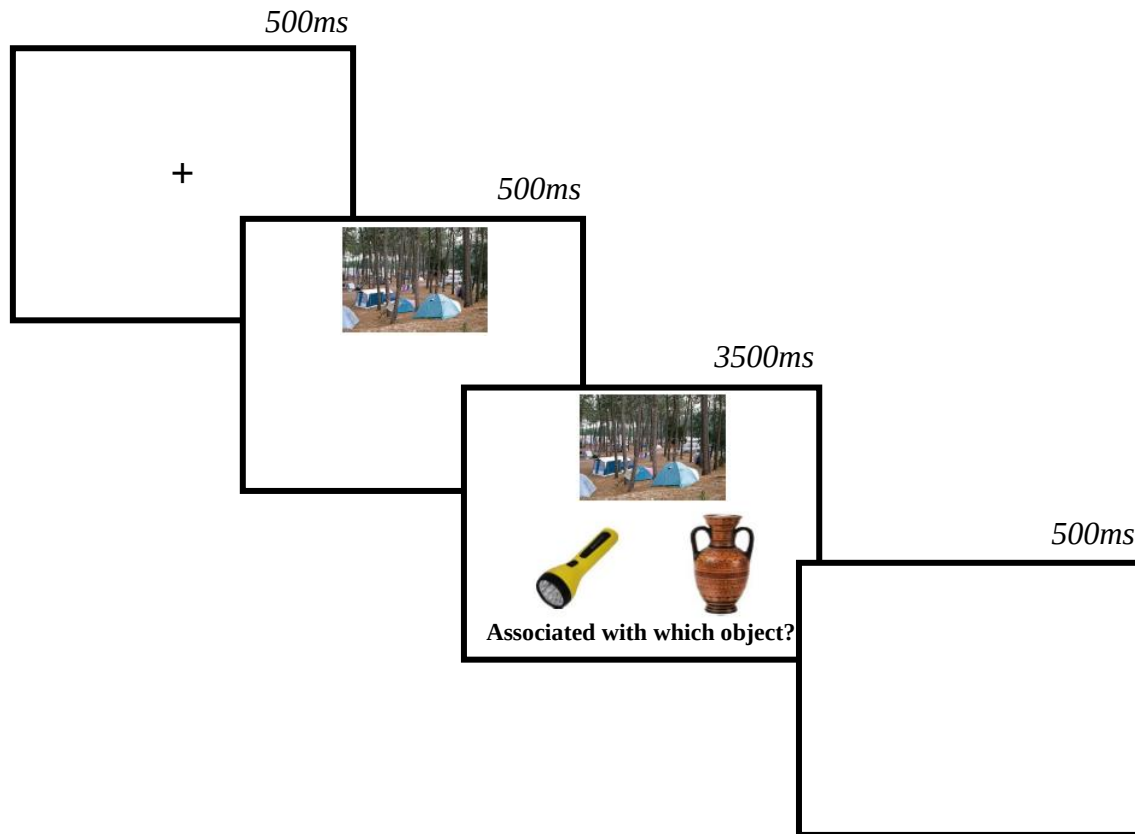


Figure 3. Illustration of a trial from the associative recognition block of the memory paradigm.

Before starting, participants were given the instructions (Appendix 2) as well as training sessions that could be repeated if necessary. For this purpose, 24 images that were not part of the experimental blocks were selected.

Logical Memory Test. A story about a woman was read to the participants, after which they were asked to reproduce from memory as accurately as possible (immediate free recall). About 20 minutes later, they were asked to provide any information recalled from the story. In case they couldn't remember it, they were given a cue such as "The story was about a woman". Moreover, by asking "Anything else?" at the end of recall allowed participants to provide any additional information out of order that might have

come to mind in the meantime (Lezak et al., 2012). Lastly, fifteen yes/no questions were asked to test recognition memory.

Go/No-Go Task. Participants were instructed to respond as quickly as possible by pressing a button whenever the target stimuli (e.g., a square with a diagonal to the right) were displayed on the computer screen and instructed not to respond (to not press the button) whenever the distractor stimulus appeared (i.e., a square with a long vertical line in the middle; Appendix 3). Each stimulus was presented for 460 milliseconds with a random interstimulus interval (ISI), ranging from 2550 to 2783 milliseconds, following Brocki and Bohlin (2004). Trials were pseudorandomized such that no more than 3 equal stimuli in a row appeared and the first 21 trials were Go stimuli, thus creating a dominant initial response (as the literature suggests, e.g., Iaboni, Douglas & Baker, 1995; Newman, 1987). Incorrect responses to a No-Go stimulus (i.e., commission errors) and non-responses to a Go stimulus (i.e., omission errors) were recorded.

Raven's Progressive Matrices. Each problem contains a pattern with a part missing which participants have to find among the six to eight options provided below that figure. They are told that the first problems of each set are simple, but as they advance, they become increasingly difficult. However, the method of thought to be used is very similar to that of previous patterns. Therefore, participants must point to the bottom piece that completes the pattern of the top figure.

Camel and Cactus Test. In this test, 5 images are displayed at a time, one at the top of the computer screen and four at the bottom. Participants are instructed to choose which of these 4 images best matches the top image (Fonseca et al., 2016). The task began with three training trials and had no time limit.

Montreal Cognitive Assessment. Participants were asked to perform different tasks starting with an alternation task adapted from the Trail Making Test B, followed by a clock-drawing task and three-dimensional cube copy. Then, they carried out a confrontation naming task of three low-familiarity animals and a short-term memory recall task involving two learning trials of five nouns and respective delayed recall after approximately 5 minutes. Also, they had to repeat a sequence of digits forward and backwards, perform a sustained attention task (target detection using tapping) and a serial subtraction task. They then were asked to repeat two syntactically complex sentences, to

perform a phonemic fluency task and a two-item verbal abstraction task. Finally, orientation to time and place was assessed.

Geriatric Depression Scale – 15 items. Participants completed a brief questionnaire with respect to changes in mood, by choosing yes or no, whichever appropriately described his or her feelings at that time (Strauss, Sherman & Spreen, 2006).

Statistical analysis

All statistical analyses of the data were performed using SPSS (Version 25).

First, independent-samples *t* tests were conducted to compare the demographic characteristics as well as the proportion of correct responses between young adults and older adults in the Logical Memory test, the Raven's Matrices, the CCT, and the Go/No-Go task. For the Go/No-Go task, accuracy, as indexed by *d'* was computed as the difference between the mean z-scores of Go hits and the mean z-scores of No-Go false alarms. To calculate the proportion of hits, we only considered the first three Go stimuli mentioned in the Materials section, due to the visual resemblance of the fourth Go stimuli with the No-Go stimuli. Impaired visual acuity is common in older adults which may have led to a low accuracy rate for this Go stimulus.

Mean accuracy (i.e., proportion of correct responses) for young and older adults in the episodic memory task was compared by repeated-measures analyses of variances (ANOVAs). Paired-samples *t* tests were performed when it was necessary to identify significantly different pairs of means. As a measure of effect size of ANOVAs, the partial eta square (η^2_p) was reported. Apart from the proportion of correct responses, we also computed two additional indexes for the associative memory task: a Semantic Congruency Index = $[(CC - II) / CC]$ and an Inhibition Index = $[(II - IC) / II]$. The Semantic Congruency Index reflects the extent to which participants' associative memory is enhanced when the objects possess a semantic relationship with the scenes, relative to when the objects do not have a semantic relationship with the scene. Thus, the greater the value, the larger the reliance on semantic congruency. The Inhibition Index reflects the degree to which participant's associative memory is hindered by the interference of a congruent distractor relative to a condition in which the distractor is incongruent. Thus, the larger the value the lower is the participant's ability to inhibit a prepotent but incorrect

response. These indexes were calculated separately for each group and analysed through independent-samples *t* tests.

Finally, potential correlations between performance in the main memory task and in the complementary tasks were explored. Statistical significance was defined as $p \leq .05$.

Results

Demographic and cognitive characteristics

Independent-samples *t* tests were conducted to examine possible differences between young and older adults. For the demographic characteristics, the two age groups were significantly different concerning their mean age (as intended), but there were no significant differences concerning the proportion of male to female participants, nor the number of years of education (cf. Table 1). For the cognitive characteristics, no significant differences were found in the Logical Memory recognition between the two groups ($p > .05$). But, on the contrary, in the Logical Memory immediate and delayed recall, Go/No-Go d' , Raven's Matrices, and CCT significant differences were observed, with young adults performing better than older adults in all these tasks (cf. Table 1).

Table 1. Analyses of demographic and cognitive characteristics between groups.

	Young Adults N = 37	Older Adults N = 38	Test Statistics	Significance	Effect size
Demographic variables					
Age	26.08 (1.79)	66.66 (4.52)	-50.853 [†]	< .001	11.744
Sex (M/F)	11/26	14/24	.427 ^{††}	.514	
Years of education	17.32 (1.16)	16.42 (3.25)	1.594 [†]	.115	
Cognitive variables					
LM I	16.16 (2.89)	13.89 (3.17)	3.234 [†]	.002	0.746
LM II	14.97 (2.51)	13.05 (3.39)	2.785 [†]	.007	0.644
LM R	13.14 (0.89)	12.79 (1.42)	1.262 [†]	.211	
Go/No-Go d'	2.33 (1.15)	1.15 (0.71)	5.365 [†]	< .001	1.240

Raven's Matrices	52.76 (4.35)	43.00 (6.68)	7.473 [†]	< .001	1.725
CCT	0.90 (0.05)	0.87 (0.09)	2.299 [†]	.024	0.531
MoCA	-	25.76 (1.76)	-	-	-
GDS	-	1.24 (1.46)	-	-	-

Note. LM I = Logical Memory immediate recall; LM II = Logical Memory delayed recall; LM R = Logical Memory recognition. [†]= *t* test, and for the effect size we used Cohen's *d*. ^{††}= Chi-Square test.

Episodic Memory Task

Encoding phase. Accuracy was analysed in a 2x2 mixed design with Relationship (congruent vs. incongruent) as a within-participants factor and Age Group (young adults vs. older adults) as a between-participants factor.

There was a significant main effect of Age Group, $F(1, 73) = 148.223, p < .001, \eta^2_p = .670$, with young adults showing greater accuracy ($M = .94$) than older adults ($M = .73$). The main effect of Relationship was not significant, $F(1, 73) = .069, p > .05, \eta^2_p = .001$, nor was the interaction effect Relationship x Age Group, $F(1, 73) = 2.228, p > .05, \eta^2_p = .030$.

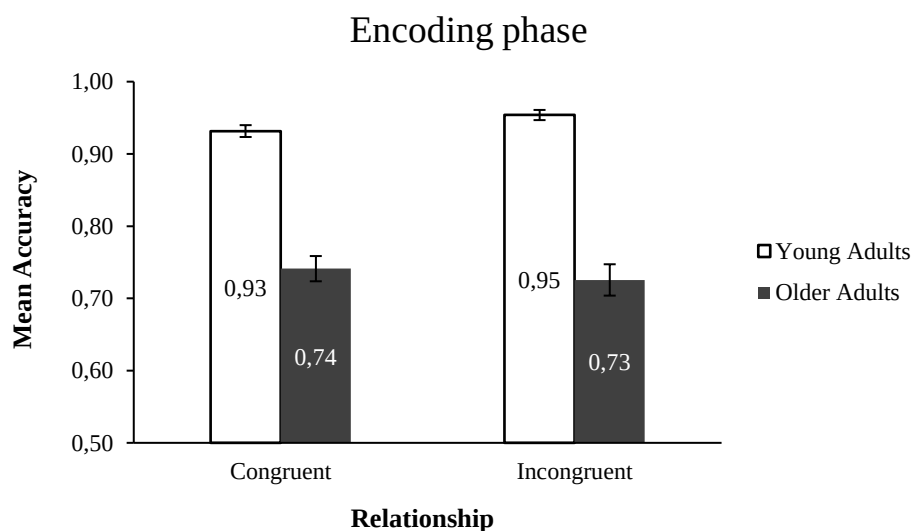


Figure 4. Mean proportion of correct responses for young and older adults for each type of relationship. Error bars represent the standard error of the mean for each experimental condition.

Retrieval phase: Item memory. In order to assess the ability to discriminate old and new objects, a 3x2 mixed design with Item Type (congruent vs. incongruent vs. new) as a within-participants factor and Age Group (young adults vs. older adults) as a between-participants factor was used. For the repeated-measures effect the Greenhouse-Geisser correction was used to correct the degrees of freedom.

The results showed a significant main effect of Item Type, $F(1.469, 107.273) = 104.887$, $p < .001$, $\eta^2_p = .590$, meaning that there are significant differences in the recognition of the items that constitute the levels of this variable. Follow-up paired-samples t tests indicated that participants identified more correctly new items ($M = .90$; $SD = .08$) than recognized old congruent [$t(74) = -7.801$, $p < .001$] and old incongruent items [$t(74) = -11.818$, $p < .001$]. Among old items, the ones coming from congruent relationships ($M = .77$; $SD = .13$) were better retrieved than those from incongruent relationships ($M = .68$; $SD = .14$) [$t(74) = 9.136$, $p < .001$]. There was also a significant main effect of Age Group [$F(1, 73) = 41.169$, $p < .001$, $\eta^2_p = .361$], with young adults ($M = .84$) demonstrating higher accuracy overall than older adults ($M = .73$). In addition, a marginal interaction effect was found between Item Type and Age Group, $F(1.469, 107.273) = 3.394$, $p = .051$, $\eta^2_p = .044$. To better understand this interaction, independent-samples t tests were conducted, which showed that the difference between the two groups was greater in the congruent [$t(68.683) = 5.511$, $p < .001$] and incongruent items [$t(69.728) = 4.332$, $p < .001$] than in the new ones [$t(50.227) = 3.928$, $p < .001$] (cf. Figure 5). Thus, the interaction reflects a smaller age difference in new items compared to old items (congruent/incongruent).

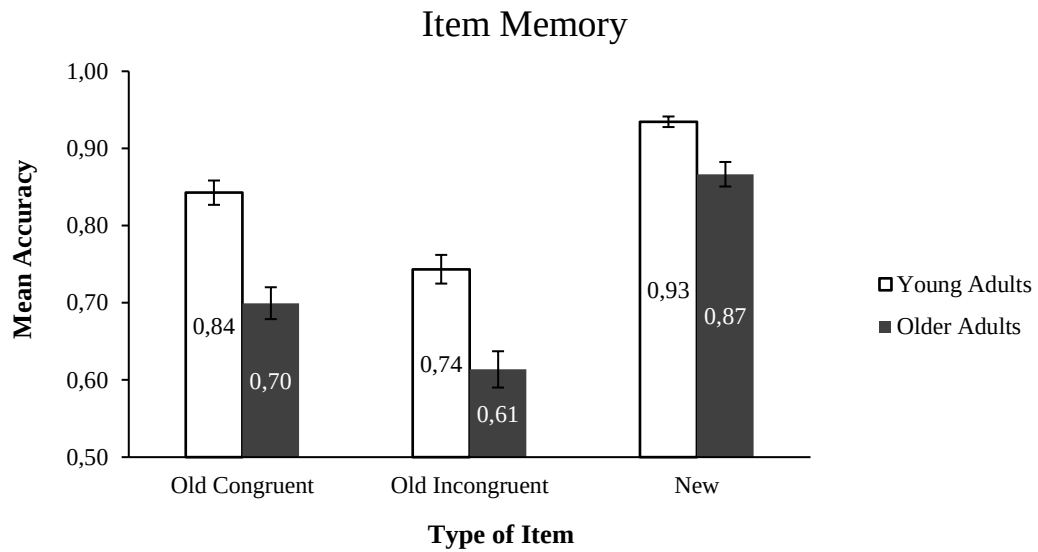


Figure 5. Mean proportion of correct responses for young and older adults for each item type. Error bars represent the standard error of the mean for each experimental condition.

Retrieval phase: Associative memory. Accuracy was analysed in a 2x2x2 mixed design with Target Object (congruent vs. incongruent) and Distractor Object (congruent vs. incongruent) as within-participants factors and Age Group (young adults vs. older adults) as a between-participants factor.

A significant main effect of Target Object was observed [$F(1, 73) = 175.010, p < .001, \eta^2_p = .706$], with higher retrieval accuracy when the target was congruent with the scene ($M = .81$) than when it was incongruent ($M = .61$). There was also a significant main effect of Distractor Object [$F(1, 73) = 115.809, p < .001, \eta^2_p = .613$], with greater accuracy when the distractor was incongruent with the scene ($M = .78$) than when it was congruent ($M = .64$). A significant main effect of Age Group was also found [$F(1, 73) = 205.145, p < .001, \eta^2_p = .738$], with young adults ($M = .86$) showing an overall higher accuracy than older adults ($M = .57$).

There was a significant Target Object x Age Group interaction effect [$F(1, 73) = 43.925, p < .001, \eta^2_p = .376$], in which the difference between young and older adults was greater for target objects incongruent with the scene [$t(73) = 12.557, p < .001$] than for target objects congruent with the scene [$t(73) = 10.648, p < .001$]. Thus, the impact of target manipulation was greater in older adults than in the young adults (cf. Figure 6).

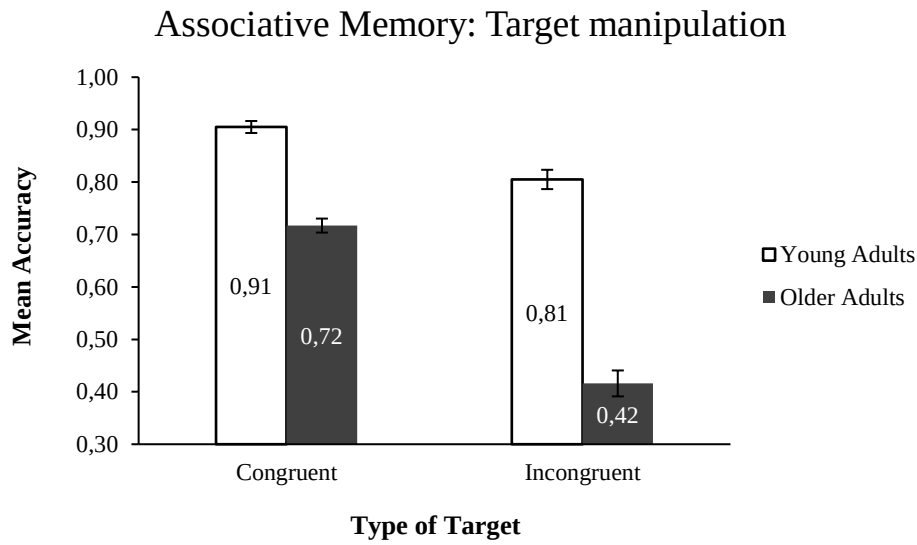


Figure 6. Mean proportion of correct responses for both congruent and incongruent target relationships for each age group. Error bars represent the standard error of the mean for each experimental condition.

There was also a significant Distractor Object x Age Group interaction effect [$F(1, 73) = 24.887, p < .001, \eta^2_p = .254$], where the difference between young and older adults was greater for distractor objects congruent with the scene [$t(73) = 12.762, p < .001$] than for distractor objects incongruent with the scene [$t(67.977) = 11.133, p < .001$]. The distractor manipulation also had a greater impact in older compared to younger adults, but now with the congruent relationship of the distractor leading to a lower accuracy (cf. Figure 7). Finally, there was no Target Object x Distractor Object interaction effect [$F(1, 73) = .348, p = .557, \eta^2_p = .005$], nor Target Object x Distractor Object x Age Group interaction effect [$F(1, 73) = .311, p = .579, \eta^2_p = .004$].

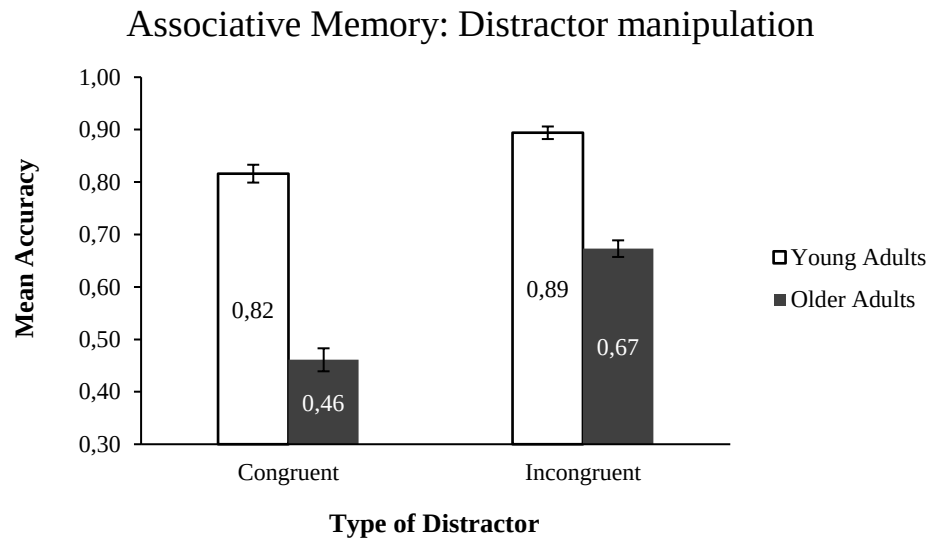


Figure 7. Mean proportion of correct responses for both congruent and incongruent distractor relationships for each age group. Error bars represent the standard error of the mean for each experimental condition.

Concerning the two computed Indexes of Semantic Congruency and Inhibition, independent-samples *t* tests were conducted to look for differences between the two age groups. For the Semantic Congruency Index, older adults showed a higher value ($M = .13$; $SD = .25$) than the younger adults ($M = .02$; $SD = .10$) [$t(73) = -2.463$, $p = .016$], confirming that associative memory decisions in older adults relied more on semantic congruency than in young adults. Additionally, regarding the Inhibition Index, older adults also showed a higher value ($M = .41$; $SD = .36$) than the younger adults ($M = .09$; $SD = .14$) [$t(73) = -4.979$, $p < .001$]. This indicates a lower inhibition ability for the older than the younger group.

Correlations between the Episodic Memory Paradigm and Complementary Tasks

For these correlations we considered four different indexes from the episodic memory paradigm: the global index of Item Memory (i.e., the participants' accuracy for old items in the Item Memory task), the global index of Associative Memory (i.e., the participants' accuracy in the Associative Memory task globally), and the Indexes of Semantic Congruency and Inhibition (cf. Statistical analysis section of the Methods).

Pearson's bivariate correlations between these indexes and four measures from the complementary tasks that showed differences between the two age groups (Raven's Matrices, Go/No-Go d' , CCT, and Logical Memory delayed recall) were conducted for each group separately.

For both age groups, we found a positive correlation between the global index of Associative Memory and the Ravens's Matrices, as well as the CCT. For the older adults' group, there was also a positive correlation between the global index of Item Memory and the Raven's Matrices. In contrast, for the young adults' group, we found a negative correlation between the Semantic Congruency Index and the Logical Memory delayed recall (cf. Tables 2 and 3).

Table 2. Pearson's bivariate correlations, and respective p -values, for the older adults' group.

Older Adults (N=38)		Raven's Matrices	Go/No- Go d'	CCT	LM II
Global Index of Item Memory	Pearson Correlation	0.350	0.056	0.210	0.279
	p -value	.031	.740	.205	.090
Global Index of Associative Memory	Pearson Correlation	0.383	0.188	0.316	0.260
	p -value	.018	.258	.053	.115
Index of Semantic Congruency	Pearson Correlation	-0.207	-0.025	-0.061	0.092
	p -value	.213	.882	.717	.583
Index of Inhibition	Pearson Correlation	0.059	0.126	0.028	-0.027
	p -value	.726	.450	.869	.872

Table 3. Pearson's bivariate correlations, and respective p -values, for the young adults' group.

Young Adults (N=37)		Raven's Matrices	Go/No- Go d'	CCT	LM II
Global Index of Item Memory	Pearson Correlation	0.142	0.153	0.173	0.156
	p -value	.400	.367	.305	.358

Global Index of Associative Memory	Pearson Correlation	0.494	0.193	0.375	0.181
	<i>p</i> -value	.002	.252	.022	.284
Index of Semantic Congruency	Pearson Correlation	0.046	0.096	-0.115	-0.377
	<i>p</i> -value	.788	.573	.498	.022
Index of Inhibition	Pearson Correlation	-0.044	0.036	-0.012	0.141
	<i>p</i> -value	.797	.835	.943	.406

Discussion

Relevance of the results

The present work investigated the role of semantic memory in the retrieval of episodic memories in healthy older adults relative to young adults.

For item memory, in contrast to what was hypothesised, our results demonstrated better item memory performance in young adults than in older adults. This goes against our prediction that assumed that item memory abilities did not rely in binding or inhibitory control, typically impaired in older adults. An important factor to take into account is that there were differences between the two groups in virtually all complementary tasks, suggesting a general difference in cognitive abilities, which may also explain the difference in item memory performance. Moreover, the emergence of an age-related difference in item memory may be explained by the fact that during encoding participants had to process two elements, one of which (i.e., scene) was visually more complex than the other (i.e., object). Thus, the two items may have been encoded differently, as older participants could have paid more attention to the more complex one (the scene), in detriment of the other (the object). Indeed, if we focus on the new items, even though the two groups showed a significant difference in the ability to detect new items, the difference was significantly smaller than in the recognition of old items (as demonstrated by the significant Age Group by Item Type interaction). For new items, participants did not need to activate any links while identifying these items, as they had not been previously associated with a context. Hence, older adults do not present such a marked disadvantage in this condition compared to the young adults. This suggests that the age-related item memory differences may result from differences at encoding.

As expected, there was a significant semantic congruency effect across both age groups, with the results showing that objects coming from congruent relationships were better remembered than objects coming from incongruent relationships. Several studies have shown the benefits of increased semantic elaboration driven by the congruency of the information with prior semantic knowledge (e.g., Staresina et al., 2009). This enhanced semantic processing is facilitated by the relationship between the information to be remembered and a previously existing schema (van Kesteren et al., 2013). Since incongruent objects have no relationships with the prior semantic knowledge (of the associated scene), their acquisition and retrieval is more difficult.

Our next hypothesis stated that there would be differences between the two groups in associative memory. As in item memory, young adults revealed a higher associative memory performance than older adults. Chalfonte and Johnson (1996) and Naveh-Benjamin (2000) studies confirmed the existence of associative recognition memory deficits in older adults, referring to their difficulty in binding different features into a cohesive unit. Also, older adults have more difficulty than young adults in inhibiting irrelevant information that can interfere with the relevant information (Connelly et al., 1991). Since in our associative memory task a distractor object was always presented, lower inhibitory control abilities may also contribute to this age effect.

We also hypothesized that when the target is congruent with the scene, both groups would perform better than when the target is incongruent. Our results confirmed that there is a semantic congruency effect for the target object, as found in item memory, such that both groups performed better when the target objects were congruent with the scene than when they were incongruent. Once again previous schemas influence participants to choose the item that is congruent with it, in this case the target object that has a congruent relationship with the scene. In complement, we predicted that when the distractor is congruent with the scene, performance is expected to be worse for both groups than when the distractor is incongruent. Indeed, congruent distractors led to a worse performance than incongruent ones. The congruency between the distractor object and the scene may cause competition with the target object, given its prior relationship with the scene, which results in impaired performance. As there is a difficulty in inhibiting the interference of semantic knowledge, participants tend to choose the item that meets their knowledge.

Lastly, we expected that older adults' associative memory would benefit more than the young adults' when the target is congruent than when the target is incongruent. Similarly, older adults were expected to have a poorer performance than young adults when the distractor was congruent than when it is incongruent. Our findings confirmed these hypotheses. Older adults benefited more than young adults when the target object was congruent with the scene than when it was incongruent. Since older adults greatly rely on their semantic knowledge, it is easier for them to achieve a better performance for congruent targets than for incongruent ones, because in the latter they would have to depend solely on their declining episodic memory. On the other hand, we found that older adults' performance was more impaired than the young adults when the distractor was congruent than incongruent. Older adults had greater difficulty in inhibiting a distractor when it was semantically congruent with the scene, as it fits into their pre-existing schemas.

Overall, these findings show that older adults rely more on semantic knowledge in order to carry out episodic memory tasks than young adults. This semantic effect was observed in both item and associative memory decisions. The Semantic Congruency Index confirmed this tendency. Importantly, the reliance on prior knowledge may promote episodic memory if the encoded episode is congruent with prior schemas. However, if the to be remembered information is incongruent with prior knowledge, then episodic decisions are hindered. These are thus two sides of the same coin. Our results also pointed out the relevance of inhibitory control in associative memory, particularly when a distractor semantically congruent with the scene interferes with the mnemonic decisions. The Inhibition Index confirmed that older adults had lower inhibitory abilities than younger adults, being more prone to memory errors when the distractor was semantically congruent.

Regarding the correlations, positive associations were found in both groups between associative memory performance and both Raven's Matrices and the CCT. Interestingly, both the Raven's as the CCT require participants to select an item among alternative options, as in our associative memory task. While the Raven's Matrices indexes abstract reasoning and fluid intelligence, the CCT taps specifically on semantic associations abilities. For both age groups, participants with superior scores in the two tests, also presented increased associative memory abilities (regardless of the nature of

the target and distractor). This suggests that both general reasoning and specific semantic memory skills promote associative recognition memory. In addition, we found a positive correlation between item memory performance and the Raven's Matrices in the older adults' group (but not in the young). Thus, for older adults, better general cognitive abilities promote episodic memory performance, even in less demanding tasks such as item recognition. Finally, in the younger group there was a negative correlation between the Semantic Congruency Index and the Logical Memory delayed recall, which demonstrates that the better the episodic memory (evaluated by the Logical Memory), the lower the benefit of semantic congruency. This correlation was not found in the older adults' group, presumably because they rely more on the use of semantic memory and therefore use less episodic memory processes (which may be more affected by age).

This research has theoretical and practical implications. At the theoretical level, it contributes to a greater understanding of the dynamics between the two long-term declarative memory systems, by elucidating how people dynamically use prior knowledge in new episodic learning. At a practical level, determining how semantic knowledge aids episodic memory is a critical step in dealing with the significant memory losses observed throughout aging. This research is thus an important approach to the development of new forms of assessment and intervention aimed at compensating for or mitigating memory deficits in older adults.

Limitations of the present study and future directions

One of the limitations of this study was that the pairs of images were selected from a database in which the semantic relationship between object and scene was determined based on pre-tests conducted with young adults (18 to 27 years old). It is possible that certain relationships could be evaluated differently by the older group. This may be one of the reasons for differences between groups in the encoding phase. This difference, in turn, may have contaminated the results at retrieval, precluding solid conclusions regarding the locus of the difference observed between young and older adults (encoding, retrieval or both). Pre-testing stimuli and their relationships in both groups would likely allow both young and older adults to start from a similar encoding level, which may influence the results in subsequent retrieval tasks.

Secondly, in the associative memory task we used only old objects as the target and the distractor of each scene. This means that objects that were the target for a particular scene could later appear as the distractor for another scene. This repetition of items may have made the task easier for some participants if, when choosing the target object, they made that decision by excluding the objects already seen during retrieval (rather than based on memory). In a future study it would be critical to overcome this limitation, by presenting more objects and avoiding object repetition during the associative memory task.

As mentioned above, the young and older group presented significant differences in all tasks (except in the recognition version of Logical Memory). Although finding these differences between age groups is not uncommon, they complicate the interpretation of the memory results. Notably, it is hard to establish whether the mnemonic differences found are due to episodic memory, semantic memory or inhibitory control skills or simply due to more general cognitive differences (as indexed by the results in the Raven's Matrices). In a subsequent study, it would be relevant to match the two groups in other dimensions and cognitive skills, besides sex and number of years of education. Relatedly, no correlations were found between the inhibition task used (Go/No-Go) and the associative memory task, even though the latter requires an inhibiting component (at least for congruent distractors). Since the Go/No-Go is a motor response inhibition task, it would be more useful to choose a task with a cognitive inhibition component (such as the Brown-Petersen task). In addition, the inclusion of other complementary measures through tasks that assess monitoring, working memory and cognitive flexibility can be an added value for understanding the memory processes of young and older adults.

Conclusion

A fundamental challenge in the study of episodic memory is to understand the role of existing knowledge in encoding and retrieval of new episodic information. This endeavour is particularly relevant in older ages where episodic memory abilities often decay, but semantic knowledge is intact. We addressed this question in an item and associative memory task in which the semantic congruency between an object and a scene was manipulated. Our results showed that older adults' episodic memory was overall

worse than that of young adults. For both groups, associative memory performance was better when the target object was congruent and worse when the distractor object was congruent, suggesting that the semantic congruency between a scene and an object affects episodic decisions. Nonetheless, older adults were more benefited by this target congruency and more impaired by the distractor congruency than young adults, demonstrating that older adults tend to choose congruent relationships, which testifies in favour of the concept of semantic schema and its inflexibility in aging.

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Appendices

Appendix A: Informed consent

CONSENTIMENTO INFORMADO

O presente estudo tem como objetivo estudar a relação entre a memória semântica e episódica ao longo do desenvolvimento. Nesse sentido solicita-se a sua participação numa série de tarefas que deverão demorar, no total, cerca de 1 hora e 30 minutos.

Não existe qualquer risco e/ou desconforto associado ao estudo em questão. Não há despesas pessoais para o participante. A sua colaboração é muito importante, porém, não é obrigatória. Caso não queira participar, sinta-se à vontade para recusar ou devolver esta folha em branco.

As informações obtidas serão analisadas em conjunto com as de outras pessoas, não sendo divulgada a identificação de nenhum participante do estudo. Os investigadores, sob a orientação da Prof^a Doutora Ana Luísa Raposo (docente da Faculdade de Psicologia da Universidade de Lisboa) e da Prof^a Doutora Filipa Ribeiro (docente da Universidade Católica Portuguesa), comprometem-se a utilizar os dados e materiais recolhidos somente para fins científicos.

A sua participação será voluntária pelo que poderá interrompê-la a qualquer momento.

Se achar que algo está incorreto ou que não está claro, não hesite em solicitar mais informações aos investigadores. Agradecemos, desde já, a sua colaboração!

Declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pelo/a investigador/a. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequência. Desta forma, aceito participar neste estudo e permito a utilização dos dados que de forma voluntária forneço, confiando em que apenas serão utilizados em âmbito científico e garantindo a confidencialidade e o anonimato.

Assinatura do participante: _____

Data: __/__/__

Os investigadores:

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Appendix B: Instructions for the episodic memory task

Instruções Gerais

Fase de Codificação:

Vão ser apresentados pares de imagens, uma corresponde a um objeto, a outra corresponde a um local. A sua tarefa consiste em decidir se o objeto e o local estão ou não relacionados. Para responder SIM carregue na tecla VERDE com o indicador direito. Para responder NÃO carregue na tecla VERMELHA com o dedo médio direito.

Tente dar as suas respostas o mais rápida e corretamente possível.

Começará por realizar alguns ensaios de treino...

Caso tenha realizado sem dificuldade os ensaios de treino poderá agora iniciar os ensaios de estudo. Alguma dúvida?

Recorde que a sua tarefa consiste em decidir se o objeto e o local estão ou não relacionados. Para responder SIM carregue na tecla VERDE com o indicador direito. Para responder NÃO carregue na tecla VERMELHA com o dedo médio direito.

Tente dar as suas respostas o mais rápida e corretamente possível.

Fase de Recuperação – tarefa de memória de item:

Vão ser apresentados objetos que viu anteriormente (na 1ª parte do estudo) e outros objetos novos (que não apareceram antes). A sua tarefa consiste em decidir se o objeto é antigo (apareceu antes) ou não (não foi apresentado antes). Para responder SIM (apareceu antes) carregue na tecla VERDE com o indicador direito. Para responder NÃO (não foi apresentado antes) carregue na tecla VERMELHA com o dedo médio direito.

Tente dar as suas respostas o mais rápida e corretamente possível.

Começará por realizar alguns ensaios de treino...

Caso tenha realizado sem dificuldade os ensaios de treino poderá agora iniciar os ensaios de estudo. Alguma dúvida?

Recorde que a sua tarefa consiste em decidir se o objeto é antigo (apareceu antes) ou não (não foi apresentado antes). Para responder SIM (apareceu antes) carregue na tecla VERDE. Para responder NÃO (não foi apresentado antes) carregue na tecla VERMELHA.

Tente dar as suas respostas o mais rápida e corretamente possível.

Fase de Recuperação – tarefa de memória associativa:

Vão ser apresentados locais que viu anteriormente e, com cada um deles, dois objetos antigos. Um dos objetos foi o objeto que apareceu antes com o local (na 1ª parte do estudo) e o outro objeto apareceu com outro local qualquer. A sua tarefa consiste em selecionar o objeto correto, ou seja, decidir qual dos dois objetos é que apareceu antes com esse local. Para selecionar o objeto da ESQUERDA carregue na tecla da ESQUERDA com o indicador direito. Para selecionar o objeto da DIREITA carregue na tecla da DIREITA com o dedo médio direito.

Tente dar as suas respostas o mais rápida e corretamente possível.

Começará por realizar alguns ensaios de treino...

Caso tenha realizado sem dificuldade os ensaios de treino poderá agora iniciar os ensaios de estudo. Alguma dúvida?

Recorde que a sua tarefa consiste em selecionar o objeto correto, ou seja, decidir qual dos dois objetos é que apareceu antes com esse local. Para selecionar o objeto da ESQUERDA clique na tecla da ESQUERDA. Para selecionar o objeto da DIREITA clique na tecla da DIREITA.

Tente dar as suas respostas o mais rápida e corretamente possível.

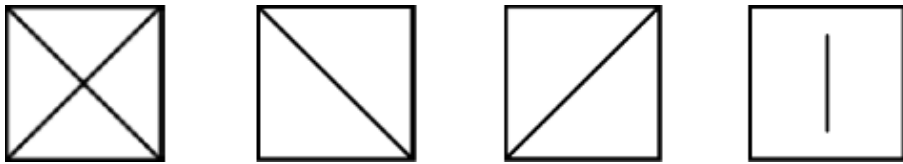
Appendix C: Instructions for the Go/No-Go task

Tarefa Go/No-Go

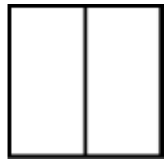
Nesta tarefa irá ver uma sequência de imagens.

Para umas terá de dar uma resposta, enquanto que para outras não.

Se vir uma destas imagens deve responder pressionando a “Barra de Espaço”:



Mas ATENÇÃO, não deve responder se vir esta imagem:



A apresentação das imagens é muito breve e deve responder o mais rápida e corretamente possível, enquanto a imagem está no ecrã!

Nos 3 primeiros ecrãs aparecerá apenas uma cruz (+) durante o mesmo tempo com que depois aparecerão as imagens. Deve preparar-se para responder a partir do 4º ecrã.

Alguma dúvida?