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Spatial layout extrapolation in aging: Underlying cognitive and executive mechanisms

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Abstract

While a large body of research has focused on the effect of aging on false memory, there are to date only a few studies that addressed this question in the field of a particular kind of memory error, boundary extension (BE), which refers to the tendency to overestimate the expanse of a previously perceived scene. This research was conducted in an exploratory perspective and pursued the objective of investigating the cognitive mechanisms involved in this phenomenon, in both young and older adults. The performances in working memory and executive functioning tasks were correlated with those of a classic BE task. While young and older adults seem to extrapolate spatial layout in equivalent proportions, BE might be due to different mechanisms at different ages: while the essential determinant of BE would be executive functioning in young adults, some of our data suggest that it would be intellectual efficiency in the elderly.

Key words: boundary extension; aging; false memory; working memory; executive functions.

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Normal aging is commonly associated with selective cognitive decline and spared abilities (e.g., Collette & Salmon, 2014; Taconnat & Lemaire, 2014; Van der Linden, Meulemans, Marczewski, & Collette, 2000), affecting functions such as processing speed (Sorel & Pennequin, 2008) and processing resources, executive functioning (e.g. Reuter-Lorenz et al. 2002; Verhaegen & Cerella, 2002), and memory (e.g., Luo & Craik, 2008; Zacks, Hasher & Li, 2000).

More specifically, human memory is subject to a multitude of errors (e.g., source misattributions, intrusions, distortions and creation of false memories; see Loftus, 1997; Roediger & McDermott, 1995; Schacter & Slotnick, 2004) and the research carried out in this field emphasises the increased propensity for memory errors in the aging subject. In order to understand and explain this phenomenon better in both the elderly and young adults, two theoretical propositions, the similarities of which supplant the differences (Corson & Verrier, 2013), have been made: the *fuzzy trace theory* (e.g., Reyna & Brainerd, 1995; Brainerd & Reyna, 2002) and the *activation-monitoring theory* (Johnson, Hashtroudi, & Lindsay, 1993; Roediger, Watson, McDermott, & Gallo, 2001). For instance, the *fuzzy trace theory* postulates the existence of different memory traces in episodic memory, encoded in parallel and stored separately: (a) verbatim traces (i.e., the perceptual or surface details of an experience, such as visual features), which favour an exact recall if they are retrieved in the memory; (b) gist information, which represents the commonalities between experiences (Arndt, 2010); this type of information is more likely to cause memory errors by activating knowledge that is compatible but not perceived and therefore possibly erroneous. According to Lövdén (2003), the age-related differences could be explained by developmental changes in the balance between verbatim processes, based on surface details, and gist processes, which could result in more memory errors (i.e., more intrusions of semantically compatible information related to the propagation of the internal activation of the semantic network when acquiring information). So, in this theoretical framework, memory errors are conceptualised as *source monitoring* errors (Johnson et al., 1993): the individual confuses the internally generated information (i.e., which refers to gist information) with the information actually perceived (i.e., verbatim trace; see Deese-Roediger-McDermott paradigm: Deese, 1959; Roediger & McDermott, 1995; see also, McDermott & Watson, 2001; Roediger et al., 2001).

While memory errors and false memories are generally associated with conditions involving high memory loads and verbal stimuli, misleading information, confusing stimulus sets (e.g., Koriat, Goldsmith, & Pansky, 2000), or delays sufficiently long to cause a weakening of the memory trace (e.g., Bartlett, 1932; Koriat et al., 2000; Loftus, Miller, & Burns 1978), other forms of memory illusions have been observed in situations in which one could expect good memory performances. One of these errors, the boundary extension phenomenon (or BE, Intraub & Richardson, 1989; see, Intraub 2007, 2010, for reviews), is known to affect visual-spatial memory and is manifested by the tendency to overestimate the spatial expanse of a previously perceived scene. While this phenomenon was first conceptualised by Intraub and colleagues (e.g., Intraub & Richardson, 1989; Intraub, Bender, & Mangels, 1992) as an *ad hoc* reconstructive memory error occurring after delays long enough to cause memory fading, Intraub and Dickinson (2008; see also Dickinson & Intraub, 2008) observed BE with both displays simulating eye scanning and recordings of oculomotor activity. Thus, spatial layout extrapolation occurs after presentation durations commensurate with an eye fixation (i.e., as brief as 250ms), and after retention intervals simulating the duration of a saccadic eye movement (42ms). The rapid occurrence of BE led Roediger (1996) to suggest that the phenomenon is located at the border between perception and memory, as spatial layout extrapolation is deployed at an early stage of scene perception (Intraub, Gottesman, Willey, & Zuk, 1996). In fact, different studies have suggested that BE is activated during scene understanding, the detection of layout automatically activating a larger spatial framework (Gottesman & Intraub, 2002). In this sense, BE would participate in the integration process of the successive eye fixations made on a scene (e.g., Dickinson & Intraub, 2008; Intraub & Dickinson, 2008; Intraub et al., 1996) and facilitate the spatial processing of visual scenes by priming the upcoming layout (Gottesman, 2011).

Although the phenomenon is described as an error related to the content of a previously perceived scene, it nevertheless has an important adaptive value, as the activation of contextual information during scene categorization enables the observer to make remarkably good predictions about the larger spatial context in which a scene takes place (e.g., Bar, 2004; Gagnier, Dickinson & Intraub, 2013). In this sense, BE would facilitate interactions with the environment through tasks such as navigation (e.g., Hale, Brown, & McDunn, 2016; Ménétrier, Didierjean, & Robin, 2017). Such an idea has been supported by neuropsychological studies and neuroimaging data (e.g., Chadwick, Mullally, & Maguire, 2013; Mullally, Intraub, & Maguire, 2012; Park, Intraub, Yi, Widders, & Chun, 2007; but see, Kim, Dede, Hopkins, & Squire, 2015).

Whereas research in the field of boundary extension has mainly been carried out in the visual modality, the phenomenon has been generalized to the haptic modality, with both blindfolded-sighted subjects and a “haptic expert” (i.e., a young woman suffering from Leber’s syndrome, which made her blind and deaf from an early age, making haptics her main mode of exploring her environment; Intraub, 2004). This observation suggests that spatial layout extrapolation is a fundamental aspect of scene perception, an idea reinforced by recent studies demonstrating that visual and haptic representations are supported by a unitary representation (Intraub, Morelli, & Gagnier, 2015). Thus, these results suggest that spatial information is at the heart of scene perception, as proposed in the *Multisource model of scene perception* (e.g., Intraub, 2012).

Developed by Intraub and her colleagues to account for the rapid deployment of spatial layout extrapolation, the *Multisource model of scene perception* (Intraub & Dickinson, 2008; Intraub, 2010, 2012) offers an alternative framework to the traditional cognitive model of scene perception. While the latter postulates that scene perception relies on a single source of information, related to the sensorial modality considered (e.g., visual), the *Multisource model* posits that scene perception relies on different sources of information, with spatial information at its core. This model is close to grounded cognition theories (Barsalou, 2008) by proposing that spatial information constitutes an egocentric framework that gives the observer a sense of the environment in which he/she is embedded. This framework is "filled in" by other sources of information, providing a multisource representation: external, with visual information, and internally-driven, with amodal information (which refers to a form of abstract perception that allows the individual not only to continue surfaces and textures just beyond the edges of the perceived view but also to complete the cropped objects mentally), and conceptual and contextual information. The categorization of the perceived scene activates expectations relative to the larger spatial context in which the scene takes place. As the visual field is graded, presenting an optimal acuity in the small foveal area (2° of the visual angle) and a low acuity in the peripheral regions (beyond 5°), the *Multisource model* posits that scene representations are graded too, with less accurate memory near the boundaries. Once a scene has disappeared, the observer will be faced with a difficulty in discriminating the really perceived (visual information) from the internally generated information (i.e. the extrapolated regions), leading to boundary extension. It follows that during retrieval, the observer is faced with a multisource monitoring task (Johnson et al., 1993) during which he/she has to distinguish between these two kinds of information. In this sense, boundary extension can be conceptualised as a source monitoring error (e.g., Intraub & Dickinson, 2008; Intraub, 2012).

While the effect of aging on memory distortions and false memory has been the subject of numerous studies (e.g., Balota et al., 1999; Dehon, 2006; Dennis, Kim, & Cabeza, 2007; Jacoby & Rhodes, 2006; Lövden, 2003; Norman & Schacter, 1997), paradoxically, few studies have focused on the effect of aging on BE and these have led to discrepant findings. While Seamon, Schleger, Heister, Landau, and Blumenthal (2002) observed increased spatial layout extrapolation in the elderly by presenting a drawing task to the participants (recall paradigm), Multhaup, Munger, and Smith (2016) observed no effect of age overall by using a recognition task with a large sample of participants (60 elderly). In the few conditions in which these authors observed an effect of age on BE, it was in the form of a decrease in BE in older people, in contrast to the observations made by Seamon et al. (2002). Although these two studies provide data about the effect of aging on BE, one of their limitations is that neither provides information about the mechanisms likely to account for these effects. If boundary extension can be conceptualised as a source monitoring error (e.g., Intraub, 2012), executive processes, thought to explain the increase in memory errors with age, may be involved. In fact, a few studies have shown that the increase in memory errors in the elderly is linked to their executive level (e.g., Butler, McDaniel, Dornburg, Price, & Roediger, 2004; Chan & McDermott, 2007; LaVoie, Willoughby, & Faulkner, 2006; Plancher, Guyard, Nicolas, & Piolino, 2009; Taconnat & Rémy, 2006). For instance, by using the DRM paradigm, Butler et al. (2004) showed that older adults with a low executive level recall more often the critical lure (i.e., the non-presented item but belonging to the same semantic theme as the list items actually perceived), while older adults with a higher executive level have a mean performance equivalent to that of young adults. Similarly, Plancher et al. (2009), using the same paradigm, showed that the production of false memories in normal aging relies on various cognitive functions, whose degree of impairment modulates this production. By testing young adults and healthy elderly adults on different dimensions of cognitive functioning such as episodic memory, semantic memory and executive functions, the authors observed not only a decrease in the correct recall performance with aging (a typical pattern of the effect of aging on memory) but also an increase in the production of semantically related false recalls and recognitions with age. Moreover, the results indicated that executive functions mediate related false memories and that episodic memory mediates related and unrelated false memories in aging.

In addition to make further observations about the effect of aging on BE, the objective of this study was to investigate the cognitive mechanisms involved in BE, in both young and elderly people. To do so, we first proposed a boundary extension task relying on a recognition test based on the classic version of the *camera distance paradigm* (CDP, e.g., Intraub & Richardson, 1989; Intraub et al., 1992), one of the most used in BE studies (e.g., Gagnier & Intraub, 2012). As a reminder, in the classic version of the CDP, the participants first have to memorise to the best of their ability a variable number of photographs (up to 40 pictures, cf., McDunn, Siddiqui, & Brown, 2014) presented for 15 seconds each. The memory of the spatial expanse of the previously perceived scenes is tested after a varying retention interval (from immediately after scene presentation to a 48-hr delay, e.g., Intraub & Richardson, 1989; Intraub & Dickinson, 2008) by asking them to evaluate whether the newly presented scenes are at the same distance, closer-up or wider-angle than the original version of the scene. Thus, boundary extension occurs when a picture that is strictly identical between the two phases of the experiment (i.e., a test picture) is rated as closer-up than the original one, indicating that the subject's memory includes extended boundaries. Such a pattern of results is typical of close-up versions of the scenes whereas the wide-angle ones generally lead to no directional distortion at all or, more rarely, to weak extrapolation (e.g., Gottesman & Intraub, 2002). Another diagnostic pattern of boundary extension is a rating asymmetry occurring when the version of the picture differs between the two phases of the experiment; pictures that are presented in a close-up version during the memorisation phase and in a wide-angle version during recognition are rated as more similar than the reverse. As in Multhaup et al.'s (2016) study, our version of the CDP consisted of a memory phase immediately followed by a recognition task. As we used the same paradigm as these authors, it seemed reasonable to expect no effect of age on BE, otherwise a decrease in spatial layout extrapolation in the elderly.

To investigate the cognitive mechanisms underlying spatial layout extrapolation and, more specifically, the potential link with executive functioning, we sought to determine whether the three executive functions (EFs) isolated by Miyake et al. (2000) – inhibition, shifting and updating – are involved in BE, in both young and older people, by using typical tests (e.g., the Stroop test; Stroop, 1935). A fourth EF - planning - was also tested. Indeed, according to Chan, Shumb, Toulopoulo, & Chend (2008), EFs refer to a set of cognitive processes and behavioural competences that include resistance to interference, the ability to sustain attention, verbal reasoning, problem-solving, multitasking, cognitive flexibility and the ability to deal with novelty, as well as sequencing and planning. Moreover, according to Balota et al.'s (1999) hypothesis, which states that memory errors depend on the efficiency of both executive functioning and working memory (WM), we also chose to test WM efficiency and processing speed. In fact, it has been shown that various difficulties encountered by the elderly do not result directly from executive difficulties but are mediated by other factors, such as decreased WM resources or deterioration in processing speed (Collette & Salmon, 2014). This latter factor is known to have an important heuristic value to explain cognitive difficulties linked to age (e.g., Salthouse, 1996) as it has been shown, for instance, that a slow-down in processing speed enhances the interference effect in the Stroop test (Verhaeghen & De Meersman, 1998). For this reason, we also chose to determine whether WM measures and processing speed are involved in BE. Thus, as BE is conceptualised as falling within the theoretical framework of memory errors (as a source monitoring error; e.g., Intraub, 2012) and knowing that links have been observed between the production of false recalls/false memories and executive functioning (e.g., Butler et al., 2004; Plancher & al., 2009), we expected, in both young and older adults, significant correlations between BE and the cognitive and executive variables tested when a cognitive function is involved in spatial layout extrapolation.

METHOD

1. Participants

1.1. Boundary extension task

Eighty participants (49 women, 31 men) took part in the BE task. Each of them was screened on different dimensions in order to ensure that they presented no psychiatric or neurological disorder that would impact cognitive performance. Thus, a health questionnaire was administered to the young and elderly adults, before ensuring they did not present any cognitive impairment with an evaluation using the Mini Mental State Exam (MMSE $\geq$ 27/30; Folstein, Folstein, & McHugh, 1975). To ensure that they presented no depressive state, the subjects were also assessed with the Geriatric Depression scale (GDS $\leq$ 5 /15; Yesavage, 1988; French adaptation by Clément, 1997). Finally, a health questionnaire including an evaluation of fine motor skills and sensory (vision/hearing) abilities was given to all the participants in order to remove those individuals presenting difficulties. Furthermore, the experience of the elderly with the computer tool was assessed in the light of the proposed task. Thus, all participants had normal or corrected-to-normal vision and audition, and none of them presented psychiatric or neurological antecedents.

After these evaluations, two subjects, one elderly and one young, were removed from the sample due to exclusion criteria. This led to a total of 78 participants (48 women, 30 men) who were divided into two groups based on their age range:

- 39 young adults (24 women, 15 men), presenting a mean age of 22.78 (SD = 1.94; age range: 18-25). These subjects were psychology students from the University of Angers (France). They presented a mean level of 16.79 years of education (SD = 2.27), which refer to all years of schooling.
- 39 healthy elderly adults (23 women, 16 men), presenting a mean age of 75.02 (SD = 1.85; age range: 72-79). They were mainly recruited through senior centers in a big city in western France, and presented a mean level of years of education of 11.34 (SD = 2.22).

All of them gave their written consent and none was aware of the objectives of the experiment.

1.2. Whole procedure participants (Boundary extension task and executive and cognitive assessment)

However, as the whole procedure lasted about 2 hours, only 46 of the subjects presented above accepted to participate in the BE task and the cognitive and executive assessment. They were divided into two groups of 23 young adults and 23 healthy elderly people whose demographic characteristics and scores on the different tests are presented in Table 1.

Inclusion criteria

In addition to the dimensions mentioned above, the crystallised and fluid intelligence of the subjects who participated in the whole procedure were evaluated using, respectively, the Vocabulary subtest of the WAIS-III (score ≥ 5; Wechsler, 2000) and Set I of the Advanced Progressive Matrices (Raven, Raven, & Court, 2003), which is constituted of 12 problems that subjects had to solve in 10 minutes (APM ≥ 5). Fluid intelligence was evaluated with reference to the works showing that interindividual differences regarding fluid intelligence are linked to interindividual differences in executive functioning (e.g., Holland & Rabbitt, 1990). The means associated with each of these inclusion criteria are presented in Table 1. A series of Student's t tests indicated that young adults performed better at each of the administered tests, with the exception of GDS, for which our two groups of participants presented equivalent scores.

	Age group		
	Young adults (N = 23)	Elderly (N = 23)	
Demographic characteristics			
Mean age	22.02 (1.90)	75.20 (1.91)	
Sex (% women)	60.87	65.22	
Education level (years)	16.3 (2.12)	10.6 (1.5)	
Inclusion criteria			***t***
MMSE (≥ 27/30)	29.74 (0.54)	28.74 (0.86)	4.704***
GDS (≤ 5 /15)	2.30 (1.79)	2.61 (2.13)	*ns*
APM (≥ 5/12)	9.70 (1.61)	8.52 (1.08)	2.905**
Vocabulary subtest of the WAIS-III (≥ 5/66)	46.09 (6.25)	39.78 (6.61)	3.323**
Working Memory assessment			***t***
Corsi blocks (Normal order, Max. 9)	5.91 (0.79)	5.09 (0.73)	3.669***
Corsi blocks (Reverse order, Max. 9)	5.09 (0.67)	4.00 (0.67)	5.491***
Digit span (Normal order, Max. 16)	9.91 (1.41)	9.30 (1.58)	*ns*
Digit span (Reverse order, Max. 14)	7.70 (1.77)	6.39 (1.62)	2.610*
Executive assessment			***t***
Clock test (Max. 7)	6.96 (0.21)	6.30 (0.76)	3.945***
TMT-A (sec)	30.42 (9.02)	48.85 (16.26)	-4.753***
TMT B-A (sec)	33.95 (15.45)	89.18 (42.95)	-5.803***
Running span (Max. 16)	12.26 (2.03)	9.91 (1.81)	4.146***
Stroop test	5.13 (7.00)	-9.91 (7.80)	6.885***

Table 1. Demographic characteristics and mean scores observed for the different cognitive tests as a function of age group (young adults, healthy elderly). The standard deviations are presented in parentheses.
* Significant difference at $p< .05$; ** Significant difference at $p< .01$; *** Significant difference at $p< .001$.

Cognitive assessment

The cognitive assessment was divided into different kinds of tasks evaluating two dimensions of cognitive functioning: executive functions (EFs) and working memory (WM).

Executive functioning assessment. Executive functioning was assessed on the basis of the three EFs isolated by Miyake et al. (2000, i.e., shifting, updating, and inhibition), and a fourth executive function, namely planning. Thus, shifting was assessed with the Trail Making Test (Lezak, 1976), which is divided into two parts consisting of connecting items. In the first part (A), the subjects have to connect digits in ascending order. In the second part

(B), they have to connect digits and letters alternately in ascending and alphabetical orders (e.g., 1-A-2-B-3-C…). In this test, the time taken to achieve each part is measured, with the time required to complete part A constituting an indicator of processing speed while subtracting the times taken for parts B and A gives an indicator of shifting abilities. Thus, the longer the time required to complete part A, the lower the processing speed. Similarly, higher TMT B-A scores reveal lower shifting abilities.

The updating process was assessed through a running span task (Morris & Jones, 1990), which is a memory task based on the presentation of sequences of a variable number of consonants (4, 6, 8 or 10), with the subject having to repeat only the last four consonants of each string. As the subjects do not know in advance the length of the sequence, they have to update constantly the items in their memory in order to maintain only the last four consonants of the sequence, which requires a high level of cognitive control (Morris & Jones, 1990; Vieillard & Bougeant, 2005). Like Plancher et al. (2009), we presented 16 different strings so the highest score was 16. Moreover, the sequences were administered in the form of three separate blocks, a familiarisation block and two test blocks, each comprising 2 sequences of each length. The strings of consonants were presented so that no more than two series of the same length were presented consecutively.

The third executive function, inhibition, was assessed through the Stroop test (Stroop, 1935), which evaluates the ability to resist interference. It is constituted of three cards administered successively. The first one displays colour patches that the subject has to name as rapidly as possible. The Stroop version used in this study was the one available in the GREFEX battery (Godefroy & GREFEX, 2008), in which three different colours are used: blue, green and red. The second card displays the names of the colours previously presented, printed in black, and the speed of word naming is measured. The third and last card refers to the interference condition. This card displays the colour names presented previously, but printed in a conflicting colour (e.g., the word red is printed in blue). As before, the subject has to name the colours as rapidly as possible, without paying attention to the verbal content of the words. Each card was constituted of 10 rows of 10 items. In accordance with Golden's (1978) adaptation, the subjects had 45s to read and name as many words or colours as possible, with the examiner measuring the number of named items. The individuals who presented an interference score higher than 0 were considered to have high inhibition abilities, while scores less than this value are considered as reflecting lower inhibition abilities.

The last executive function evaluated in this study was planning (see, Chan et al., 2008), which was assessed through the clock drawing test (Critchley, 1953). In this task, the subjects have to complete the face of a clock (i.e., mark in the 12 digits of the hours) and draw the hands to indicate a specific time (e.g., 11 past 10). One point is awarded on 7 quality criteria for the execution of the instructions (e.g., the 12 digits are present, placed in the correct order, well placed spatially, and the two hands are drawn). The normal and expected score in young adults and/or adults without cognitive difficulties is 7/7, scores below this value revealing planning difficulties.

Working memory assessment. WM was understood according to Baddeley's model (Baddeley & Hitch, 1974; Baddeley, 2000) by determining the involvement of the central administrator and the two subsidiary systems, whose efficiency was evaluated with both the digit span subtest of the WAIS-III (Wechsler, 2000) and Corsi blocks (Corsi, 1972). The former assesses the efficiency of the phonological loop and relies on the presentation of lists with an increasing number of digits (from 2 to 9). Sequences of digits are given orally at the rate of one per second by the experimenter and the subject has to repeat each of them in the same order immediately afterwards. Thus, the memory span refers to the number of digits included in the longest sequence that is accurately repeated. Corsi blocks are based on the same principle as the digit span task, with the difference that they evaluate the visuo-spatial sketchpad through a tapping task of cubes arranged on a board. The examiner taps a gradually increasing sequence of blocks (from 2 to 9), which the subject has to reproduce in the same sequential order. As in the digit span task, the visuo-spatial span is determined from the longest sequence correctly repeated. For the purpose of this study, we used the standardisation of the Corsi blocks proposed by Kessels, van Zandvoort, Postma, Kappelle and de Haan (2000). These two tasks were also administered in reverse order to examine the efficiency of the central administrator. As Kessels et al. (2000) did not carry out a standardisation of the reverse order version of Corsi blocks, we used the sequences proposed in a French study by Fournier and Albaret (2014).

2. Apparatus of the BE task

The BE task was presented on a 15-inch MacBook Pro portable computer (2006) and was run by Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993). The participants were tested individually and were seated at a distance of approximately 50cm from the computer screen during the experiment.

3. Stimuli

In the BE task, 20 visual scenes, each one in two versions, were used, leading to a total of 40 photographs. Each of these scenes - which depicted natural scenes of a central object or a cluster of objects photographed in a natural setting - was produced in a close-up and a wide-angle version. The central object covered, on average, approximately 40% of the total surface area of the close-up version of the scenes, and the wide-angle version of the same scenes was constructed so that there was a mean difference of 16.5% between the two versions (cf. Figure 1 for an example), a difference that is known to lead to prevalent boundary extension compared to greater differences (Hale, Brown, McDunn, & Siddiqui, 2015).

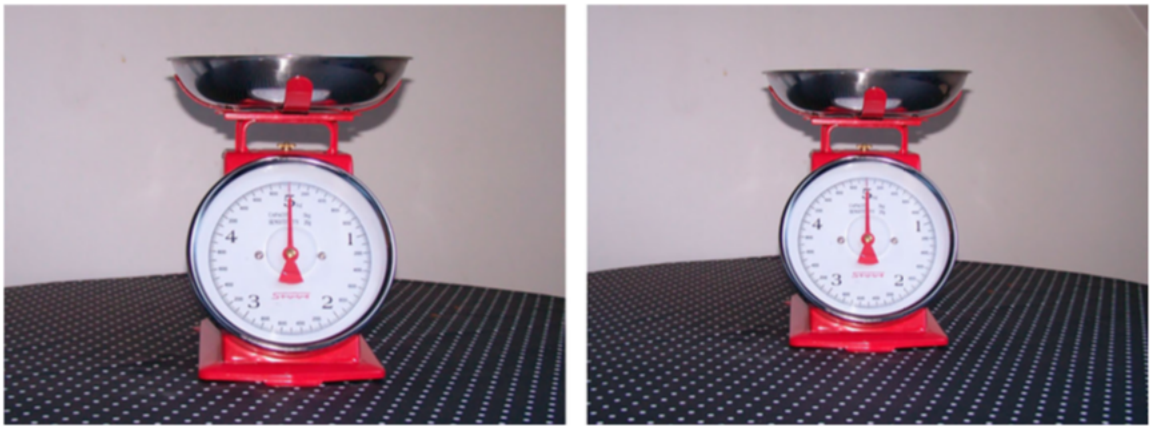

Figure 1. Example of photographs presented during the experiment; the picture on the left depicts a close-up version of the scene, while the photograph on the right depicts a wide-angle version of the same scene.

Half of the scenes were used as test stimuli, i.e., photographs that were strictly the same between the two phases of the experiment. Thus, pictures that were presented in a close-up version during memorisation and in the same close-up version during recognition are referred to as CC trials, whereas the wide-angle pictures used as test photographs are referred to as WW trials. In the same way, half of the pictures were used to create “different trials” in which pictures were presented in a different version between the two phases of the experiment, and will be referred to as “distractors”. The pictures presented in a close-up version during the memorisation phase and in a wide-angle one during recognition are referred to as CW trials, and the reverse as WC trials. Moreover, an additional photograph was used as an example during the familiarisation phase of the experiment.

The photographs were centered on a white screen and were presented in dimensions of 15*11cm.

4. Procedure

As the whole procedure lasted about 2 hours, it was administered in two sessions. In the first, the health questionnaire was administered to the participants, before they were evaluated on the different inclusion criteria described previously. In the second session, held a maximum of three days later, the participants were evaluated on both WM and executive functioning. The order of the different tasks assessing cognitive functioning was chosen at random and then kept constant across the participants. The session began with the clock drawing test and was followed by the Corsi blocks, the running span task, the TMT, the Stroop test, ending with the digit span task. The boundary extension task was administered after these tests and is described below.

Boundary extension task

The participants were exposed to a classic version of the camera distance paradigm, a memory task developed by Intraub and colleagues (e.g., Gagnier et al., 2013; Intraub & Richardson, 1989; Intraub et al., 1992) and consisted of two experimental phases, a memorisation phase followed by a recognition test.

Memorisation. During the memorisation phase, the participants were exposed to 20 photographs (10 close-up and 10 wide-angle views) that they had to memorise to the best of their abilities, by paying attention as much to the content of the scenes as to their background (e.g., Gagnier & Intraub, 2012). Photographs were presented in a random order and stayed on the screen for 15s, a duration enabling an in-depth processing of visual information. Each photograph was preceded by a 600-ms central fixation-point and followed by a 500-ms visual mask (i.e., visual noise) on the center of which appeared a red fixation-point to prevent scanning effects. The visual mask was then followed by a 1-s blank screen, so that the ISI lasted approximately 2s.

Recognition. Memory was tested immediately after the end of the memorisation phase. It was explained to subjects that they would see the previously memorised scenes again, in a random order, with the difference that some of them may have been modified in relation to the distance at which they appear. Thus, the participants had to rate on a five-point scale (ranging from -2 to 2) whether each newly presented scene seemed to them at the same distance as (0 value of the scale), closer-up (a little: value -1; a lot: value -2) or wider-angle (a little: value 1; a lot: value 2) than the original one. The participants also gave their confidence rating for each of their responses, by indicating whether they were *sure*, *pretty sure* or *not sure*. They were also given an *"I don't remember that picture"* option. During the recognition test, the participants had no time constraints to validate their answers.

During the experiment, the versions of the test stimuli and the distractors were counterbalanced from one participant to another, which led us to produce four different experimental scripts. Thus, the subjects perceived a total of 5 CC (a close-up picture tested by a close-up), 5 WW (a wide-angle tested by a wide-angle), 5 CW (a close-up tested by a wide-angle) and 5 WC (a wide-angle tested by a close-up) trials. In addition, the participants underwent a familiarisation phase before the experiment in order to become familiar with the type of stimuli and their presentation duration.

For the subjects who participated in the BE task only, the order was the same, with the exception that the procedure was administered in one session, without cognitive/ executive assessment.

RESULTS

1. *Effect of aging on boundary extension*

The results presented in this section are based on data from all participants (N = 78).

Confidence ratings

Overall, participants reported being *sure* of their responses in 48.14% of cases, *pretty sure* in 40.13% and *not sure* in 11.41%. They declared having forgotten a picture in 0.32% of cases. Young participants declared being *sure* of their responses in 47.56% of cases, *pretty sure* in 41.54%, *not sure* in 10.65%, and having forgotten a picture in 0.25% of cases. The elderly participants were *sure* of their responses in 48.72% of cases, *pretty sure* in 38.72% and *not sure* in 12.18%. They had forgotten a picture in 0.38% of cases. There was no difference between young and elderly people in these self-evaluations (all independent t-tests *ns*).

Memory distortion analyses

Test picture analysis (CC and WW trials). In order to determine whether a memory distortion occurred, the .95 confidence intervals associated with each mean boundary rating were computed (e.g., Gagnier et al., 2013; Gottesman & Intraub, 2002). Thus, a mean boundary rating equivalent to 0 revealed the absence of directional memory distortion, whereas a negative significant value indicated BE and a positive significant one, boundary restriction (BR), the opposite effect to BE. The analyses, which were computed on all the trials (except the forgotten pictures) and higher-confidence rating trials (*pretty sure* and *sure* responses), led to the same pattern of results, with the exception of observations made for WW trials in older participants, a difference that is described below.

Figure 2 depicts the mean boundary ratings observed for the test trials (CC and WW) in younger and older adults when the analyses were computed on higher-confidence trials. Whether the analyses were performed on all or on higher-confidence trials, the results indicated that CC trials led to significant boundary extension in both young and older adults. However, the WW trials led to different patterns of results when the analyses were run on all or on higher-confidence trials. Thus, when the analyses were computed on the higher-confidence ratings, they indicated no directional memory distortion in young adults, but a BE effect was observed in the elderly (cf. Figure 2). This latter pattern of results differed slightly when the analyses were computed on all responses, as the mean boundary rating observed for the elderly led to no significant directional memory distortion (as for young adults), although this effect almost reached significance (.95 CI = [0.0007; -0.3238]).

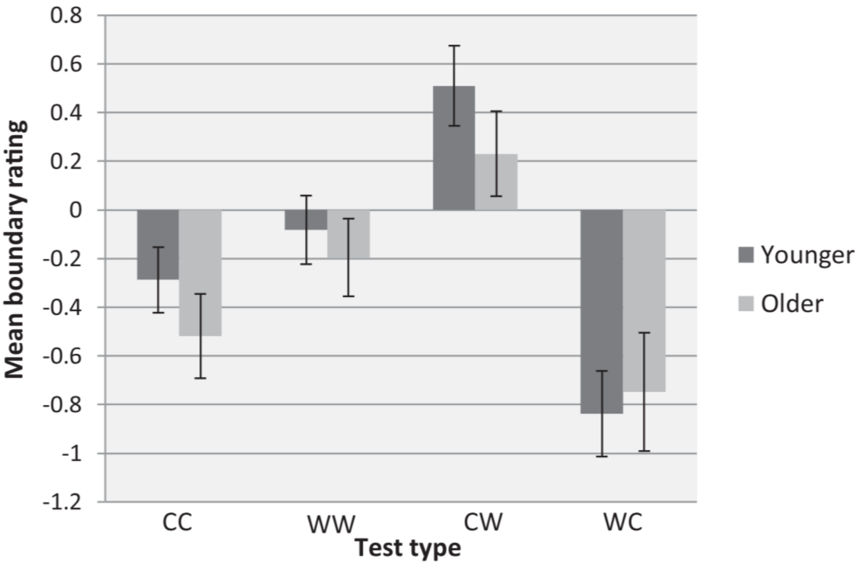

Figure 2. Mean boundary ratings observed for the different trial types (CC, WW, CW, WC) as a function of age group for higher-confidence trials (*pretty sure* and *sure* responses). The error bars represent the .95 confidence intervals. [CC: close-up picture tested by a close-up, WW: wide-angle tested by a wide-angle, CW: close-up tested by a wide-angle, WC: wide-angle tested by a close-up].

A 2*2 mixed-design ANOVA computed on subjects' mean boundary ratings with Age group (young, old) as a between-subjects factor and Test type (CC, WW) as a within-subjects factor revealed the same pattern of results when the analyses were run on all response trials and on higher-confidence trials. For this reason, we focus on the observations made with the latter that offers a better accuracy (e.g., Intraub, Daniels, Horowitz, & Wolfe, 2008). Thus, the ANOVA revealed a significant effect of Test type, $F(1, 76) = 20.440$, $p < .001$, $\eta^2 p = .212$, indicating greater boundary extension in CC trials, which were evaluated as closer-up than WW trials. The results also indicated a marginal and negligible effect of Age group, suggesting that the elderly would present a trend toward more BE than young adults, $F(1, 76) = 3.417$, $p = .068$, $\eta^2 p = .043$. Moreover, the Test type* Age group interaction was not significant, $F(1, 76) < 1$, $p = .323$, $\eta^2 p = .013$.

Distractor analysis (CW and WC trials). As before, the analyses were run twice, on all and higher-confidence trials, and led to the same pattern of results. So, only the observations made on the higher-confidence confidence trials are reported here. A 2 (Age group: young, old) *2 (Test type: CW, WC) mixed-design ANOVA computed on subjects' mean boundary ratings showed an effect of Test type, $F(1, 76) = 153.412$, $p < .001$, $\eta^2 p = .669$, indicating that the participants used the rating scale correctly and were able to discriminate the close-up and wide-angle versions of the same scene. The results also indicated no effect of Age group, $F(1, 76) < 1$, $p = .354$, $\eta^2 p = .011$, and no significant interaction, although the latter effect almost reached significance in spite of a very weak effect size, $F(1, 76) = 3.867$, $p = .053$, $\eta^2 p = .048$.

The analyses were also computed on the absolute values of the distractors to ensure that the magnitude of the ratings differed between the CW and WC conditions, CW trials being rated closer to 0 than WC ones when a picture is remembered as a wider-angle view than the studied picture (Gottesman & Intraub, 2002). This is a key question, as this asymmetry constitutes one of the specific diagnostic patterns of BE (e.g., Hale et al., 2015; Intraub & Dickinson, 2008; Intraub et al., 2008). Thus, the absolute values of the WC trials were determined by multiplying the negative mean boundary ratings by -1 (Czigler, Intraub, & Stefanics, 2013). As previously, a 2 (Age group: young, old) *2 (Test type: CW, WC) mixed-design ANOVA was computed, which indicated a significant effect of Test type, $F(1, 76) = 22.153$, $p < .001$, $\eta^2p = .226$, suggesting that CW trials were evaluated as more similar (i.e., closer to 0) than WC trials. No effect of Age group, $F(1, 76) < 1$, $p= .413$, $\eta^2p = .009$, and no significant interaction between the two variables were observed, $F(1, 76) = 1.610$, $p= .208$, $\eta^2p = .021$.

In summary, the results reported a marginal effect of age on BE, suggesting that the elderly tend to extrapolate spatial layout more than young adults (cf., Seamon et al., 2002). In addition to not being significant, the effect size associated with this effect reported a weak effect ($\eta^2p = .043$, accounting for 4.3% of the variance; cf., Cohen, 1988), leading us to conclude, by caution, in the absence of an effect of age on BE. Overall, these results replicate those of Multhaup et al. (2016), who observed no effect of aging on BE with a recognition task.

2. Cognitive and executive mechanisms underlying boundary extension

As a reminder, only 46 of the subjects presented above accepted to participate both in the BE task and the cognitive and executive assessment. We note that the results presented in the previous section are also observed on this smaller sample[1].

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[1] Indeed, similar patterns of results emerged when the analyses were computed on the subsample of subjects who also participated in the cognitive and executive battery (N =46). As the results were identical when the analyses were run on all trials and on higher-confidence trials, only the results observed with the latter are reported here. Moreover, for brevity, only the results of test pictures are exposed in detail. Thus, for CC and WW trials, a 2*2 mixed-design analysis of variance computed on participants mean boundary ratings with Age group as a between-subjects factor and Test type as a within-subject factor revealed an effect of Test type, $F(1, 44) = 4.636$, $p = .037$, $\eta^2p = .095$, with greater BE for CC trials, no effect of Aging, $F(1, 44) = 1.709$, $p = .198$, $\eta^2p = .037$, and no significant interaction between these two variables, $F(1, 44) < 1$, $p = .637$, $\eta^2p = .005$. For distractors, the pattern of results was the same as with the whole sample of participants, with the exception of a significant interaction between Test type and Age group, $F(1, 44) = 7.612$, $p = 0.008$, $\eta^2p = .147$, revealing that older participants evaluated the CW trials closer to 0 than the younger ones, $t(44) = 2.942$, $p = 0.\ 005$, $d = 868$.

2.1. Performance of young and older adults in the different cognitive and executive tasks

Table 1 presents the mean performances and associated standard deviations observed for young and older adults in the different cognitive and executive tasks. A series of Student's t tests indicated that the young participants performed better than the older ones at all the tasks, except the digit span when administered in a normal order.

2.2. Cognitive mechanisms underlying boundary extension

To investigate the cognitive mechanisms underlying spatial layout extrapolation in young and elderly adults, a series of Pearson correlations was computed (see, Appendices A and B) between the mean scores observed for different BE indicators and the scores obtained in the different cognitive tasks (administered to assess WM and EF). Concerning BE indicators, we made the choice of focusing on the most sensitive and representative ones: CC trials, which are described as a more sensitive measure of BE than WW (e.g., Dickinson & Intraub, 2008), and the CW-WC difference (computed on absolute values), which constitutes a key indicator of BE (e.g., Gottesman & Intraub, 2002). Furthermore, in Appendix C, we report correlations computed on the CW indicator, which may constitute, to us, an indicator of boundary extension that could be used in correlational analyses. Due to the small sample size, correlational analyses computed for each group of subjects were conducted in an exploratory perspective.

In this section, we suppose that when a cognitive function is involved in BE, there should be significant correlations between the scores obtained on executive and WM tests and measures of BE. However, due to the small sample size, we chose (1) not to report correlations too close to the commonly accepted significance threshold (i.e., with a p-value between .04 and .05) and (2) to only report the correlations that were significant both when computed on all the responses (*not sure*, *pretty sure* and *sure* responses) and on the higher-confidence ratings (*pretty sure* and *sure* responses) of the BE task. For better reliability, correlations on the higher-confidence ratings (*pretty sure* and *sure* responses) are reported here.

Correlation analysis for young adults

A series of Pearson correlations was computed between the mean scores of the two selected indicators of the BE task and the scores obtained in the tasks aimed at evaluating the efficiency of working memory (Corsi blocks – normal and reverse, and the digit span task – normal and reverse) and executive functioning (clock drawing test, TMT-A, TMT B-A, running span, Stroop).

Thus, the mean CC scores obtained in the BE task correlated positively with the scores obtained in the Corsi blocks (normal order, r = .512, p = .012), and in the Stroop test (r = .567, p = .005), So, higher visuo-spatial span and higher inhibitory abilities are associated with more positive scores in the BE task (i.e., scores indicating less BE). Indeed, as indicated by the positive linear relationship, individuals with higher visuo-spatial span and inhibitory abilities would be more prone to BR errors. This suggests that visuo-spatial span and inhibition could be involved in BE and may constrain spatial layout extrapolation. Such a pattern of results was corroborated by the analyses computed on the CW-WC difference (absolute values; see Appendix A)[2].

To investigate better the mechanisms underlying spatial layout extrapolation, we chose to compute correlations *a posteriori* between the different indicators of the BE task and the scores observed for the different cognitive tasks used for our inclusion criteria: the MMSE, the APM and the Vocabulary subtest of the WAIS-III. The results revealed no significant correlation.

Correlation analysis for the elderly

As before, a set of Pearson correlations was computed between the mean scores of the two indicators of the BE task and the scores obtained in the tasks aimed at evaluating the efficiency of working memory and executive functioning. The pattern of results observed with the elderly differed from that of the young adults, as there was, according to our criteria, no significant correlation between the selected BE indicators and the scores obtained in the different cognitive and executive tasks. Moreover, none of the correlation computed *a posteriori* between the indicators of the BE task and the scores obtained in the different tasks used for our inclusion criteria was significant (But see, Appendix C).

Test of homogeneity of correlation coefficients

To examine the possibility that different cognitive mechanisms are mobilised in BE as a function of age, we tested the differences observed between young and older adults for significant correlations. All the analyses were computed via Statistica PL software, which includes tests of homogeneity of correlation coefficients. So, each significant correlation reported previously was compared to the corresponding correlation coefficient observed for the other age group. For the CC indicator, the tests of homogeneity reported a significant difference between our two age groups for correlations on the Stroop test only (p = .030). Concerning the CW-WC indicator, we observed a marginal effect for the Stroop test only (p = .082). All the other comparisons are not significant.

[2] The CW-WC difference (on absolute values) has to be interpreted in the same way as the boundary rating scale when it is used with CC and WW trials, negative values indicating BE, while positive values indicate BR. The more the value is different from 0, the higher the memory distortion is.

DISCUSSION

This research pursued the objective of investigating the cognitive mechanisms involved in boundary extension, in both young and older adults. To do so, we asked older and young adults to carry out a BE task based on a paradigm similar to that used by Multhaup et al. (2016). As well as these authors, we observed that, when confronted with a recognition task, young and older adults seem to extrapolate spatial layout in equivalent proportion, leading us to conclude to the absence of an effect of aging on BE in these conditions. According to the *Multisource model* (Intraub, 2012) and source monitoring theories (Johnson et al., 1993), these results indicate that, during the memory test, our participants encountered difficulties in discriminating the information actually perceived from the internally-driven information (the mentally extrapolated area of the scene), a difficulty that was observed in equivalent proportions in young and older adults.

However, precautions must always be taken when interpreting a null effect. Indeed, the results obtained by Seamon et al. (2002) are closer to those generally reported in the literature on false memory (i.e., increased memory errors in aging, regardless of the study paradigm used; e.g., Balota, et al., 1999; Dehon, 2006; Dennis et al., 2007; Norman & Schacter, 1997; Plancher et al., 2009) and question the effect of the nature (more or less sensitive) of the BE task used (recall task in Seamon et al., for example). Moreover, BE may differ in several ways from other memory errors described in the literature (for instance, relying on verbal stimuli or misleading information), one of whose characteristics is to include verbal – and more abstract – information than sensorial information, as found in the visual scenes we used. So, the absence of an age effect between young and older adults could result from these experimental features.

As age alone may not account for the effect of aging on memory (Corson & Verrier, 2013), this research has tried to investigate the cognitive mechanisms underlying spatial layout extrapolation (quality of executive functioning, of WM, and processing speed), in both young and older adults. The results revealed different patterns in our two age groups, suggesting that the cognitive mechanisms underlying spatial layout extrapolation would differ in younger and older adults.

Cognitive mechanisms underlying BE in young adults

With regard to the cognitive mechanisms underlying spatial layout extrapolation, it appears that executive functioning might be one of the essential determinants of BE in the young adults. Indeed, EFs such as inhibition and updating would be involved in BE and may constrain spatial layout extrapolation by allowing the observer to discriminate more easily the actually perceived scene from the mentally extrapolated area. Such a result fits with previous studies showing the involvement of EFs in false memory creation, with a high level of executive functioning leading to better memory performance whatever the age. For instance, in a developmental perspective, it has been shown that EFs are central to the difficulties encountered by children or the elderly when they have to identify the source of memorised information (e.g., Butler et al., 2004; Chan & McDermott, 2007; Karpinsky & Scullin, 2009). Thus, the correlation between BE and EF empirically corroborates the idea that BE can be conceptualised as a source-monitoring error, as postulated by Intraub in her *Multisource model of scene perception* (e.g., Intraub, 2012).

In addition, the fact that inhibition and updating would be involved in BE emphasizes the importance of controlled processes in constraining spatial layout extrapolation (e.g., Intraub et al., 2008). According to the correlations observed in the present study, inhibition may be the most important executive component involved in BE, which would control the activation level of extrapolated information and, consequently, allow a better discrimination between the different sources of information (e.g., Zacks et al., 2000). This is in agreement with the results of numerous studies showing the greater efficiency of inhibitory processes of young people compared to older adults, resulting in more frequent failures or errors in memory with age (e.g., Hasher, Zacks, & May, 1999; Hasher, Quig, & May, 1997; see, Devitt, Tippett, Schacter, & Addis, 2016, for a recent study in the autobiographical domain).

Moreover, unsurprisingly, it appears that visuo-spatial span would be involved in spatial layout extrapolation: as previously, higher visuo-spatial abilities might constrain BE, leading these individuals to make more BR errors than those with lower abilities. Otherwise, the fact that verbal abilities may not be involved in BE calls for different types of comments: in addition to the choice of the task (digit span task), which can be discussed, we can also assume the presence of independent processing channels, an idea supported for instance by the fact that sound does not interfere with BE (e.g., Gagnier, 2010, see also, Intraub et al., 2015, for a description of these experiments; Munger & Multhaup, 2016).

A last point that needs to be noted is that the correlations observed suggest that the higher the inhibition and visuo-spatial span, the more the individual will be prone to boundary restriction, the memory error opposite to BE (cf., CC indicator). As EF tasks (e.g., the Stroop test) mobilise attentional abilities, we can hypothesise that these processes would constrain spatial layout extrapolation by focusing attention on the details of the perceived scene (i.e., local rather than global scene processing). Thus, these results, yet to be consolidated, suggest that young adults with higher cognitive abilities would favour an analytical processing of their visual environment.

Cognitive mechanisms underlying BE in the elderly

With the exception of the digit span (normal order), the elderly performed less well than young adults in the different cognitive and executive tasks administered, a typical effect of aging on cognitive functioning (see however Verhaegen's meta-analyses [2011], which demonstrated that executive control decline in aging has been exaggerated). Moreover, on correlational analyses, we observed a different pattern of results from that described for younger adults, suggesting that BE would rely on different cognitive mechanisms as a function of age, a result that was underpinned by correlation coefficients homogeneity tests.

In fact, none of the different cognitive and executive functions tested seemed to underlie spatial layout extrapolation.

While various authors have observed that the quality of EFs is a predictor of false memory creation, with older adults with a high executive level presenting better memory performance (e.g., Plancher et al., 2009), it seems unwise to conclude now that EFs such as inhibition, flexibility or updating, as well as WM or processing speed, would play no role in spatial layout extrapolation in the elderly. On the contrary, it seems plausible that other factors might contribute to explaining the absence of a significant correlation observed in the present research; one potential candidate could be attentional resources. In normal aging, whereas impairment in executive functioning is associated with retrieval processes and, more specifically, source-monitoring difficulties, a decrease in attentional processes is responsible for memory errors during encoding (e.g., Butler et al., 2004; Corson & Verrier, 2013). Otherwise, the fact that none of the EF tasks correlates with BE raises the question of the conservation of the factor structure of EFs described in Miyake et al.'s model (2000), with different authors doubting its conservation during aging (e.g., De Frias, Dixon, & Strauss, 2006, 2009). For instance, De Frias et al. (2009) demonstrated that older adults with a higher executive level present a more differentiated factor structure (3 factors) than their counterparts with lower abilities (one factor).

Although executive functioning may be one of the essential determinants of spatial layout extrapolation in younger adults, intellectual efficiency might be at least one of the determinants of BE in the elderly (See, Appendix C), a pattern that was not observed in younger participants (but see, Chapman, Ropar, Mitchell, & Ackroyd, 2005). In fact, the results suggest that older adults with a higher fluid and crystallised intelligence may present greater BE, leading us to hypothesise that these individuals would favour a more global processing of the visual scenes than their counterparts with lower abilities. This better ability to predict the probable surrounding space suggests a greater tendency in these individuals to enrich the information, which has already been observed among others in the field of text processing (Gold & Arbuckle, 1995; Gould, Trevithick, & Dixon, 1991; Le Bouëdec, Martins, Iralde, Gauthier, & Delaporte, 2002). Thus, according to the *Multisource model* (e.g., Intraub, 2012), the elderly with higher crystallized and fluid intelligence might be more likely to create a richer peripheral/contextual portion of the representation surrounding what is perceived, possibly leading to greater BE. Moreover, as the opposite pattern (i.e., more BR errors) was observed in younger participants with higher cognitive abilities, we can hypothesise the existence of a different approach to visual scenes as a function of age, in which younger adults would favour an analytical processing and older adults with higher abilities a global processing of their environment. Naturally, the relationship observed between BE and intelligence (fluid, crystallised) needs to be replicated and investigated further.

That said, from a methodological point of view, the sample of older individuals who participated in cognitive and executive assessment seems too small to overcome the variability inherent in aging. Indeed, it has been shown that the heterogeneity of the profiles of the elderly is more marked than that of young adults, whose profiles are generally more homogeneous (De Beni, Palladino, Borella, & Lo Presto, 2003). Such an idea is evidenced by the performance profiles of older people in the BE task, with standard deviations being higher than those for young adults.

Conclusion

In conclusion, it appears that BE, an adaptive memory error involved in spatial cognition, may be due to different mechanisms at different ages. While in young adults the favoured explanation would primarily be based on source-monitoring difficulties linked with EF, in the elderly this explanation would be paired with the intellectual efficiency level and, more speculatively, with the hypothesis of a decrease in attentional processes, impacting the quality of encoding. In this way, the hypothesis of impaired attentional processes could be understood in a complementary approach. Moreover, as we just wrote, the results suggested that cognitive abilities would be linked with different ways of processing visual information as a function of age.

Finally, such results and conclusions need to be put into perspective, as this is, to our knowledge, the first study exploring the cognitive mechanisms underlying spatial layout extrapolation. Because some factors known to have an effect on the performance of older adults (i.e., attentional factors) were not taken into consideration, further research is required not only to determine the relative contribution of the factors mentioned above, but also to evaluate the effect of differential abilities in these factors, in both young and older adults. More generally, the aim of these studies will be to identify better the strength or vulnerability with aging of the different cognitive functions and specify the conditions enabling the optimisation of mental functioning in older adults.

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Appendix A: Pearson's correlations coefficients observed for young adults

Pearson Correlations

	CC	**CW-WC (Absolute values)**	**MMS**	**APM**	**Vocabulary**	**Corsi blocks (Direct)**	**Corsi blocks (Reverse)**	**Digit span (Direct)**	**Digit span (Reverse)**	**Clock test**	**TMT A**	**TMT B-A**	**Running Span**	**Stroop**
CC	—													
CW-WC (AV)	-0,375	—												
MMS	0,095	0,087	—											
APM	-0,087	0,049	-0,095	—										
Vocabulary	0,241	0,139	0,034	0,179	—									
Corsi blocks (Direct)	0,512 *	0,415 *	0,157	-0,093	0,112	—								
Corsi blocks (Reverse)	0,203	0,173	0,317	-0,397	-0,035	0,53 **	—							
Digit span (Direct)	0,325	0,406	0,028	0,208	0,387	0,155	-0,088	—						
Digit span (Reverse)	0,202	0,279	0,008	0,222	0,43 *	0,142	0,1	0,426 *	—					
Clock test	0,046	0,076	-0,105	0,094	0,387	-0,024	0,028	-0,013	0,332	—				
TMT A	-0,228	-0,033	-0,007	-0,096	0,263	-0,165	-0,334	-0,063	-0,129	-0,051	—			
TMT B-A	-0,09	-0,001	-0,446 *	0,05	-0,177	-0,114	-0,11	0,133	-0,142	0,038	0,15	—		
Running Span	0,113	0,41	0,189	0,221	0,418 *	0,326	-0,118	0,167	0,492 *	0,136	0,391	-0,231	—	
Stroop	0,567 **	0,568 **	0,339	0,266	0,403	0,085	-0,064	0,428 *	0,202	0,122	-0,079	-0,059	0,238	—

* $p < .05$, ** $p < .01$, *** $p < .001$

As the pattern of results was similar when the correlations were computed on all the responses (not sure, *pretty sure* and *sure*) of the BE task on the one hand, and on the higher confidence ratings (*pretty sure* and *sure* responses) on the other hand, only the results observed in the latter are reported here. Note that only the correlation coefficients reported in the two first columns respond to our research hypotheses.

Appendix B: Pearson's correlations coefficients observed for the elderly

Pearson Correlations

	CC	CW-WC (Absolute values)	MMS	APM	Vocabulary	Corsi blocks (Direct)	Corsi blocks (reverse)	Digit span (Direct)	Digit span (Reverse)	Clock test	TMT A	TMT B-A	Running Span	Stroop
CC	—													
CW-WC (AV)	0,468 *	—												
MMS	-0,165	0,341	—											
APM	0,053	-0,276	0,298	—										
Vocabulary	-0,229	-0,19	0,411	0,474 *	—									
Corsi blocks (Direct)	0,069	0,156	0,109	0,169	0,088	—								
Corsi blocks (reverse)	-0,185	-0,124	-0,156	0,436 *	0,438 *	0,368	—							
Digit span (Direct)	-0,129	0,028	0,327	0,062	0,285	0,643 ***	0,384	—						
Digit span (Reverse)	-0,021	0,016	0,076	0,19	0,451 *	0,545 **	0,709 ***	0,628 **	—					
Clock test	0,311	0,109	-0,149	0,349	0,131	0,437 *	0,441 *	0,183	0,414 *	—				
TMT A	0,287	0,036	-0,096	-0,406	-0,348	-0,361	-0,522 *	-0,192	-0,372	-0,56 **	—			
TMT B-A	0,112	0,141	-0,212	-0,35	-0,237	-0,375	-0,307	-0,407	-0,296	-0,504 *	0,55 **	—		
Running Span	-0,089	-0,21	0,014	0,141	0,185	0,452 *	0,41	0,519 *	0,323	0,316	-0,346	-0,406	—	
Stroop	-0,068	0,08	-0,161	-0,338	-0,085	0,222	0,086	0,32	0,336	0,234	0,063	-0,171	0,064	—

* p < .05, ** p < .01, *** p < .001

As the pattern of results was similar when the correlations were computed on all the responses (not sure, *pretty sure* and *sure*) of the BE task on the one hand, and on the higher confidence ratings (*pretty sure* and *sure* responses) on the other hand, only the results observed in the latter are reported here. Note that only the correlation coefficients reported in the two first columns respond to our research hypotheses.

Appendix C
Complementary analyses (CW trials)

In this section, we present complementary analyses that we computed on CW trials, which, to us, might constitute an indicator of BE in correlational analyses.

To understand our reading of the CW distractors items, we first specify that we are reasoning here on individual data, as is the case when calculating correlations, rather than on mean values, as it is usually the case in BE studies. Moreover, if some of these results are rarely observed in ecological situations, we retain them here as plausible from a theoretical point of view and interpret them as an indicator of BE in correlational analyses: indeed, while correct answers in the CW condition (in which the memory of a close-up picture is tested with the wide-angle version of the same scene) refer to the positive values of the BE rating scale, a picture rated as the same as the studied one (0 value of the scale) indicates that the scene is remembered as a wider-angle view than the studied picture, thus revealing BE (Gottesman & Intraub, 2002). In the same way, rating the test picture as closer (negative values of the scale) would indicate that the observer's memory includes greater spatial expanse than in the original one and thus, that the memory includes (very) extended boundaries. This idea is also corroborated by the interpretation of the five-point rating scale (For explanations about the CW indicator, see also, Munger & Mulhaup, 2016). While it seems unlikely to observe negative means with CW indicator, this possibility may be more plausible in the case of individual data. Correlation coefficients observed for each age group are presented in Table 2.

Pearson correlations	**Young adults**	**Elderly**
MMS	-0,119	-0,028
APM	0,365	-0,54 **
Vocabulary	0,185	-0,551 **
Corsi blocks (Direct)	0,206	0,028
Corsi blocks (Reverse)	-0,181	-0,409
Digit span (Direct)	0,239	-0,085
Digit span (Reverse)	0,256	-0,132
Clock test	0,423	0,001
TMT A	0,177	0,411
TMT B-A	0,045	0,166
Running Span	0,457 *	-0,104
Stroop	0,469 *	0,165

* p < .04, ** p < .01, *** p < .001

Table 2. Pearson correlation coefficients observed for the CW indicator (Young adults and elderly).

Correlation analysis for young adults. The results indicated positive correlations between the CW indicator of the BE task and a) the scores obtained in the running span task (p = .028) and b) the Stroop test (p = .024), corroborating the hypothesis that EF would be involved in BE in young adults: higher updating and inhibitory abilities are associated with more positive scores in the BE task (i.e., positive values of the rating scale, referring here to correct answers). In this case, the more positive the rating on CW trials, the larger the rated difference between the remembered view of the close-up stimulus and the visible view of the wide-angle test picture, which is consistent with less BE for the close-up stimulus[3].

Correlation analysis for the elderly. The CW scores correlated significantly with those obtained in the APM (p = .008) and the Vocabulary subtest of the WAIS-III (p = .006): the elderly with higher fluid and crystallised intelligence score lower in the BE scale (i.e., negative values of the scale, referring in this case to BE errors). Surprisingly, this suggests that older adults with a higher fluid and crystallised intelligence would be more prone to BE than those with a lower efficiency (See, Discussion).

Test of homogeneity of correlation coefficients. We observed a significant difference for correlations on the APM (p = .003), the Vocabulary subtest (p = .014), and a marginal effect for the Running span (p = .066).

[3] Note, however, that these two correlations were no longer significant when a Bonferroni correction for multiple comparisons was applied.