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"When did you see it?" The effect of emotional valence on temporal source memory in aging

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Abstract

Previous studies consistently showed age-related differences in temporal judgment and temporal memory. Importantly, emotional valence plays a crucial role in older adults' information processing. In this study, we examined the effects of emotions at the intersection between time and memory, analysing age-related differences in a temporal source memory task. Twenty-five younger adults (age range 18-35), 25 old adults (age range 65–74), and 25 old-old adults (age range 75-84) saw a series of emotional pictures in three sessions separated by a one-day rest period. In the fourth session, participants were asked to indicate in which session (1, 2, or 3) they saw each picture. Results showed that old-old adults tended to collocate negative pictures distant in time, while positive stimuli were remembered as more recent than real, compared to neutral pictures. To a lower extent, people over 65 showed the same pattern of results. In contrast, emotional valence did not affect younger adults' temporal positioning of stimuli. Current findings fit well with the Socio-Emotional Selectivity Theory's assumptions and extended the literature on the positivity effect to temporal source memory.

Keywords: time, emotions, positivity effect, list order, older adults.

Introduction

As humans, we have the innate ability to 'travel in time', and people spontaneously interpret events within temporal dimensions. Perception of time is crucial in human life, as it allows to build personal identity, learn from experience, and guide future behaviour. The temporal dimension is a core aspect of human's episodic memory (Tulving, 2002). Indeed, when remembering specific information, often people had to recall also when that information was collected. Generally speaking, memory for temporal details -as well as other contextual details- of the encoded information is labelled source memory (Palombo et al., 2021).

Notwithstanding its importance for humans, the ability to keep track of time does not work as a perfect clock. Instead, people's time perception is influenced by a range of internal and external factors, such as emotions (Droit-Volet & Gil, 2009). For instance, when people experience fear, time passed is judged as longer than real, due to the acceleration of the internal clock (Droit-Volet et al., 2011). Emotions affect not only time perception, but also memory, influencing information’s encoding, storage, and retrieval processes (Palombo et al., 2021). Research suggested that this effect emerged as the emotional context guides attentional processes toward the information. As a result, the attention during the encoding phase is enhanced, leading to stronger memory consolidation of the information and stronger resistance to forgetting (Talmi et al., 2019). However, research on younger adults found that the emotional nature of a stimulus may either foster or hamper memory for temporal context (Petrucci & Palombo 2021).

In this study we focused on age-related changes in temporal source memory and temporal preferences as a function of emotional valence. Aging research demonstrated that both time perception and memory decline in older people. On the one side, studies showed that older people had shorter time estimates compared to younger adults (Carrasco et al., 2001), probably related to attentional deficits (Lamotte & Droit-Volet, 2017). Older adults are generally less accurate in time judgments compared to younger adults, subjectively perceiving time as going faster (Micillo, et al., 2021). On the other side, episodic memory is impaired in typical aging (Salthouse, 2019), and source memory - and temporal source memory specifically - have been found significantly compromised (Noack et al., 2013; Old & Naveh-Benjamin, 2008). Yet, few research investigated the role of emotional valence of the stimuli on temporal source memory. Palumbo and colleagues (2018) analyzed this topic, revealing that older adults’ source memory benefitted from the emotional valence of the stimuli (both positive and negative). However, the improvements in older adults’ source memory accuracy were not enough to overcome age-related differences, as emotional valence positively affected also younger adults’ source memory performance.

In a shift from previous research, in this study we aimed at examining age-related differences in the typology of errors made when judging temporal context, rather than in accuracy per se. Past studies on temporal source memory analysed accuracy (i.e., correct recall of when something happened), ignoring the way in which people were wrong when their answer was inaccurate. However, looking at accuracy alone may lead to found similar absolute deviations from the accurate response for positive and negative stimuli. Therefore, past studies potentially missed to identify age-related tendencies in wrongly put events in time, depending on their emotional valence. Hence, in this study for the first time we examined people's tendency to judge closer or more distant than actual the emotional vs. neutral stimuli they saw. We based this choice and built our hypotheses on the Socio-emotional Selectivity Theory (SST - Löckenhoff & Carstensen, 2004). According to the SST, due to the progressive shrinking of the temporal horizon, personal goals change, and older adults prioritize emotional wellbeing. This motivational shift impacts on attentional and recall processes, assuming the form of a preference for positive stimuli, and an aversiveness toward negative stimuli, that has been called "positivity effect" (Di Domenico et al., 2015; Reed et al., 2014). Therefore, we wanted to test whether affective valence can influence older adults' preferences in temporal collocation of past events. We hypothesized that older adults would "keep closer" in time positive events, while at the same time "pushing" negative events distant in time. Our expectations relied not only on theoretically based reflections, but also on some empirical findings on related topics. For instance, past research indicated that, when free to decide the order of presentation of neutral and emotional stimuli, older adults demonstrated a preference to see negative pictures at last, move them away in time (Löckenhoff et al., 2012).

To reach our goal, we adopted a classical source memory task, requesting to remember when each item was seen among three possible timepoints. However, as we were interested in the direction of the temporal judgments more than in its accuracy, rather than presenting both old and new (filler) items, we presented only old items. This allowed to not confuse age-related effects in source memory with item-memory deficits (Mirandola & Toffalini, 2018).

A further contribution of the current study is that we considered two groups of older adults: from 65 to 74 (old adults - OA) and 75 and over (old-old adults - OOA). This choice was guided by previous research indicating that aging is not a uniform process and that people over 75 years show important differences in cognitive and emotional functioning compared to younger cohorts (Lecce et al., 2019; Schmitter-Edgecombe & Simpson, 2001). We expected that the role of emotional valence on temporal source memory would be greater in the OOA group, as the susceptibility to the emotional valence should intensify accordingly to the progressive reduction of the time horizon.

Furthermore, we moved a step forward toward an ecological approach expanding the timeframe (i.e., six days) in which the information was presented. In fact, in daily life individuals are exposed to information over the course of several days and are often required to remember when the information was acquired within longer timeframes.

Finally, as previous studies suggested that older people's lower performances in temporal source memory were related to impaired executive functioning (Rajah et al., 2010), in this study we selected participants to be matched in terms of cognitive functioning and educational level, hence excluding the confounding effect of those abilities on temporal source memory performance.

Methods

Participants

Twenty-five YA (age range 18–35), 25 OA (age range 65–74), and 25 OOA (age range 75-

84) participated in the study. Sensitivity analyses were conducted with G*Power after data collection to compute the minimum effect size that can be detected given alpha (0.05), power (0.80), and sample size (75). Results indicated that we had enough power to detect partial $\eta^2 \geq 0.14$.

Demographic information and statistics are presented in Table 1. YA were undergraduates from the University of Chieti-Pescara who participated for course credit. OA and OOA were community-dwelling people from both North and Centre of Italy, reporting being in good mental and physical health. They did not receive monetary reimbursement for their participation. Exclusion criteria included treatment for memory problems and/or medical conditions that could affect cognitive functioning. For the two older adult groups only, a further exclusion criterion was a score below 26 on the Mini-Mental State Examination (MMSE), a widely used screening for cognitive difficulties. No participants were excluded based on this criterion

[Table 1]

Procedure and Materials

The study was approved by the IRBP of the Local Committee. Written informed consent was obtained before data collection. Participants took part in four experimental sessions, each one followed by a one-day rest period. Hence, the whole study lasted seven days (Figure 1). Details on the procedure, the stimuli selection, the task creation, and the TAI score calculation are provided in the Supplemental material. In the first session, background information (age, gender, education), cognitive functioning (MMSE, Digit Span, FAS) and affective measures (PANAS) were collected. In each study session (from Session 1 to Session 3), participants saw 16 pictures, eight emotional (four positive and four negative) and eight neutral pictures. Pictures were randomly presented in the centre of a computer screen for 30s with a 1s interstimulus interval (i.e., fixation cross). Participants were asked to closely watch each picture as they would need to describe them. The stimuli presented consisted of 48 pictures extracted from the IAPS database (Lang et al., 2005).

The source memory task was administered in the fourth session. Importantly, the participants were not informed that memory for temporal information would be assessed. Participants were presented in random order all the 48 stimuli previously showed. Each picture appeared in the centre of the screen and was preceded by a 1s fixation cross. As soon as each picture appeared, participants were asked to indicate in which session (1, 2 or 3) they had seen that item by selecting the corresponding button on the computer keyboard.

To inspect the pattern of errors in recalling the temporal order of the stimuli, we created a Temporal Accuracy Index (TAI), based on the formula:

$$TAI = recalled\ session - actual\ session$$

Therefore, the TAI score reflects the tendency to move items backward or forward in time. Scores approaching zero reflected an accurate temporal collocation, with no bias toward any temporal direction. Negative TAI scores indicated the tendency to remember items as earlier than real, while positive TAI scores reflected the tendency to consider items as more recent than real. We computed total TAI scores for positive, negative, and neutral items, by averaging the TAI scores of the corresponding items. The total TAI scores range from -1 to +1.

[Figure 1]

Results

We performed a 3 x 3 mixed ANOVA, with Age group (YA, OA, and OOA) as the betweensubject factor, and Valence (positive, neutral, and negative) as the within-subject factor. TAI score was entered as dependent variable. Means and standard deviations are presented in Table 2. Post-tests that followed up on any significant effect were corrected for multiple comparisons using Tukey HSD tests. Effect sizes are reported as partial eta squared.

[Table 2]

Results revealed a non-significant main effect of Age group, $F(2, 72) = 0.39$, $p = .678$, partial $\eta^2 = .01$. A significant main effect of Valence emerged, $F(2, 144) = 28.42$, $p < .001$, partial $\eta^2 = .28$. Post hoc analyses indicated that negative stimuli had lower TAI score compared to both positive and neutral stimuli, *p*s < .001. TAI scores for neutral and positive pictures did not statistically differ, $p = .075$. Crucially, a significant Age x Valence interaction emerged, $F(4, 144) = 12.13$, $p < .001$, partial $\eta^2 = .25$ (see Figure 2).

Focusing on within-group differences, simple effects analyses (with Tukey HSD test) revealed that emotional valence did not affect temporal collocation in YA. Specifically, TAI scores for positive, neutral, and negative items did not significantly differ in this age group, all *p*s ≥ .922. Regarding OA, a significant difference in TAI score between positive and negative pictures emerged, $p = .012$. Neutral items did not differ from either positive or negative stimuli, *p*s ≥ .226. Finally, in the OOA group TAI scores were significantly different at each level of valence: positive vs. neutral, $p = .002$; neutral vs. negative, $p < .001$; and positive vs. negative, $p < .001$.

Examining between groups differences, we found that YA and OA did not significantly differ in any TAI scores, *p*s ≥ .536. However, OOA showed significantly higher TAI scores in positive items compared to both YA, $p < .001$, and OA, $p = .029$. Furthermore, in negative items OOA showed lower TAI scores compared to YA, $p = .001$. No differences emerged between OOA and OA, in negative pictures, $p = 489$. Finally, no age-related differences emerged in neutral items, between OOA and the other two age groups, *p*s ≥ .999.

Analyses on source memory accuracy without considering the directionality of the errors are reported in the Supplemental material.

[Figure 2]

Discussion

In this study, we examined the effect of emotional valence in a source memory task, comparing younger adults to older adults. To better examine the effect of aging on temporal collocation of emotional stimuli, we further distinguished between old (OA - from 65 to 74) and old-old (OOA - over 75) adults. Furthermore, in refining the literature on the effect of emotions on temporal source memory, we offer a novel contribution by shifting the interest from analysing accuracy, to examining people's tendency to collocate events close or distant in time. Specifically, we analysed the pattern of errors made by people in the temporal positioning of affective stimuli.

Our findings revealed that emotional valence affected older adults' source memory, but it had no impact on younger adults. In line with the SST's assumptions, we found that older people tended to collocate positive and negative stimuli on the opposite ends of a virtual temporal line (Mammarella et al., 2016). Specifically, the OOA group "pushed away" negative stimuli, and put closer in time positive stimuli, compared to neutral stimuli. Therefore, our findings suggest that people aged over 75 remember negative stimuli as happened earlier, and positive stimuli as happened more recently, compared to neutral stimuli. However, contrary to our expectations, people aged 65 to 74 years did not show such a positivity effect. In this group, only a difference between positive and negative stimuli emerged, being these two located on the opposite end of the temporal line. Interestingly, this did not happen in the YA group. This result may reflect an enhanced susceptibility to emotional contents in people aged 65 to 74 years, which is strengthened in the oldest age group.

When we examined age-related differences, we found that YA and OA did not differ in stimuli's temporal positioning, irrespective of the emotional valence. Only people aged 75 and over showed significant differences in source memory for emotional (but not neutral) stimuli compared to younger adults. Overall, these results highlight the importance not to consider people aged over 65 as a homogenous "old adults" population (Ruthig et al., 2019).

Current results echoed the large body of research on the positivity effect in aging (Grühn et al., 2007), extending our knowledge of this phenomenon by revealing a bias in temporal judgments, a facet of source memory that was not previously investigated. From a theoretical point of view, both the selective avoidance (placing events far away in time) of negative stimuli, and the preference (placing events closer in time) for positive stimuli may serve an emotion regulatory scope in aging. Generally speaking, subjective time perception helps to create and maintain a sense of identity. For instance, research in the autobiographical memory field claimed that people move forward and backward memories to maintain a positive sense of self. Positive memories are located closer in time, while failures and negative memories are attributed to an "old" self (Wilson et al., 2009). Current results fit well with this perspective: older people's tendency to move close positive memories, and to move away negative memories, may serve to regulate current affective states. Nevertheless, as we did not measure affective regulation skills, this speculation should be further tested by assessing individual differences in emotional competence.

In considering the present findings, it is important to acknowledge that the older adults recruited were not fairly representative of the aging population. Indeed, cognitive functioning and educational level are usually lower for older people compared to younger adults, while in our study participants in the three age groups did not statistically differ on these variables.

We purposely selected matched samples to avoid the confounding effects of cognitive skills and background characteristics on temporal memory. However, future research should test whether the pattern of results found in this study is maintained in a more representativeness sample of older adults.

Current results were discussed in relation to the literature on source memory, deriving the conclusion that older adults remember the temporal context of emotional stimuli differently than younger adults. However, it is important to note that, as we were interested in systematic biases in temporal collocation of events, we presented only pictures which were effectively seen, without testing participants' item memory. Hence, it may be that older adults did not remember pictures, but, as they were forced to choose when they saw them, they simply put them close/distant in time due to their apparent familiarity. Research showed that familiarity – the feeling of "knowing" something - is influenced by emotional valence. For instance, older adults tended to feel positive stimuli more familiar than negative and neutral one (Piguet et al., 2008). Therefore, future studies should elucidate this point by examining item-memory performance along with source memory.

Finally, in this study we moved toward ecological validity by using an experimental design aiming at closely mirror daily life's demands. Specifically, we adopted for a longer lag between the encoding and the recollection phases compared with previous research. We believe that the longer retention interval may explain why, contrary to the study of Palumbo and colleagues (2018), we did not find better source memory for emotional stimuli, but the opposite. Indeed, our results showed that, for older adults, emotional pictures were characterized by higher biases in temporal judgments compared to neutral pictures. It may be that emotions successfully increase the binding process in the short term, but this benefit deteriorates quickly. We believe that our study is a first contribute to the call for studies using longer retention intervals (Petrucci & Palombo, 2021), but future studies should directly examine the impact of the delay between encoding and retrieval on memory. Also, a future avenue for research is the use of dynamic, rather than static stimuli, which can enlighten how older people remember and collocate in time actions, rather than pictures or words, depending on their emotional valence.

To conclude, our findings shed some preliminary light on how older people build their temporal line for past events and which errors they could make in estimating when bad (good) things happened. On a speculative note, these errors may serve as emotion regulation strategies, reflecting motivational shifts in older adults' resources allocation useful to promote wellbeing (Scheibe & Carstensen, 2010). To investigate the potential benefits (or negative effects) of emotions on the ability to bind temporal context to events have crucial implications for older adults' daily functioning. For instance, in real life, the tendency to remember negative events as more distant in time than real may translate into older adults remembering a fall as more remote than it actually was. This, in turn, can have severe consequences for individuals' mental and physical health. Future studies could extend the research from retrospective source memory to prospective memory. An intriguing possibility to be investigated is that in older people the positivity effect would extend in imaging the future, such as planning and predicting events.

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Disclosure of interest

The authors report there are no competing interests to declare.

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Tables

Table 1. Means (standard deviations) of background variables as a function of age group.

	YA	**OA**	**OOA**	**Statistics for group differences**
Age	24.00 (5.42)	68.80 (2.80)	79.48 (2.16)	F (2, 74) = 1553.15 $p < .001$
Gender (M/F)	11/14	11/14	10/15	χ^2 (2) = .11 p = .947
Years of education	12.52 (2.99)	11.88 (3.53)	12.16 (2.76)	F (2, 74) = 0.27 p = .767
MMSE	-	26.97 (1.37)	27.60 (1.73)	F (1, 48) = 2.07 p = .157
Digit Span Forward	7.36 (1.66)	7.12 (1.13)	7.20 (1.32)	F (2, 74) = 0.19 p = .824
Digit Span Backward	5.60 (1.53)	5.24 (0.93)	5.44 (1.47)	F (2, 74) = 0.46 p = .636
FAS	13.89 (3.06)	13.49 (2.43)	13.82 (2.60)	F (2, 74) = 0.16 p = .855
PANAS -Positive affect	31.40 (7.98)	31.72 (6.15)	31.68 (7.72)	F (2, 74) = 0.01 p = .986
PANAS - Negative affect	19.28 (5.73)	18.28 (5.58)	18.16 (4.78)	F (2, 74) = 0.33 p = .722

Table 2. TAI scores as a function of age group and emotional valence.

	YA	**OA**	**OOA**	**Tot**
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
TAI Positive	-.04 (.18)	.03 (.18)	.20 (.23)	.06 (.21)
TAI Neutral	.02 (.17)	-.01 (.11)	.01 (.11)	.01 (.13)
TAI Negative	-.03 (.16)	-.13 (.21)	-.23 (.19)	-.13 (.20)

Figure 1.

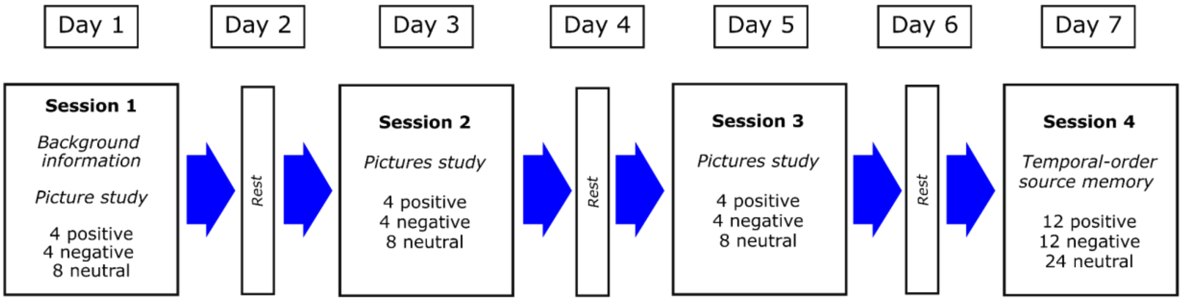
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Session 1
Background information
Picture study
4 positive
4 negative
8 neutral
Rest
Session 2
Pictures study
4 positive
4 negative
8 neutral
Rest
Session 3
Pictures study
4 positive
4 negative
8 neutral
Rest
Session 4
Temporal-order source memory
12 positive
12 negative
24 neutral

Figure 2.

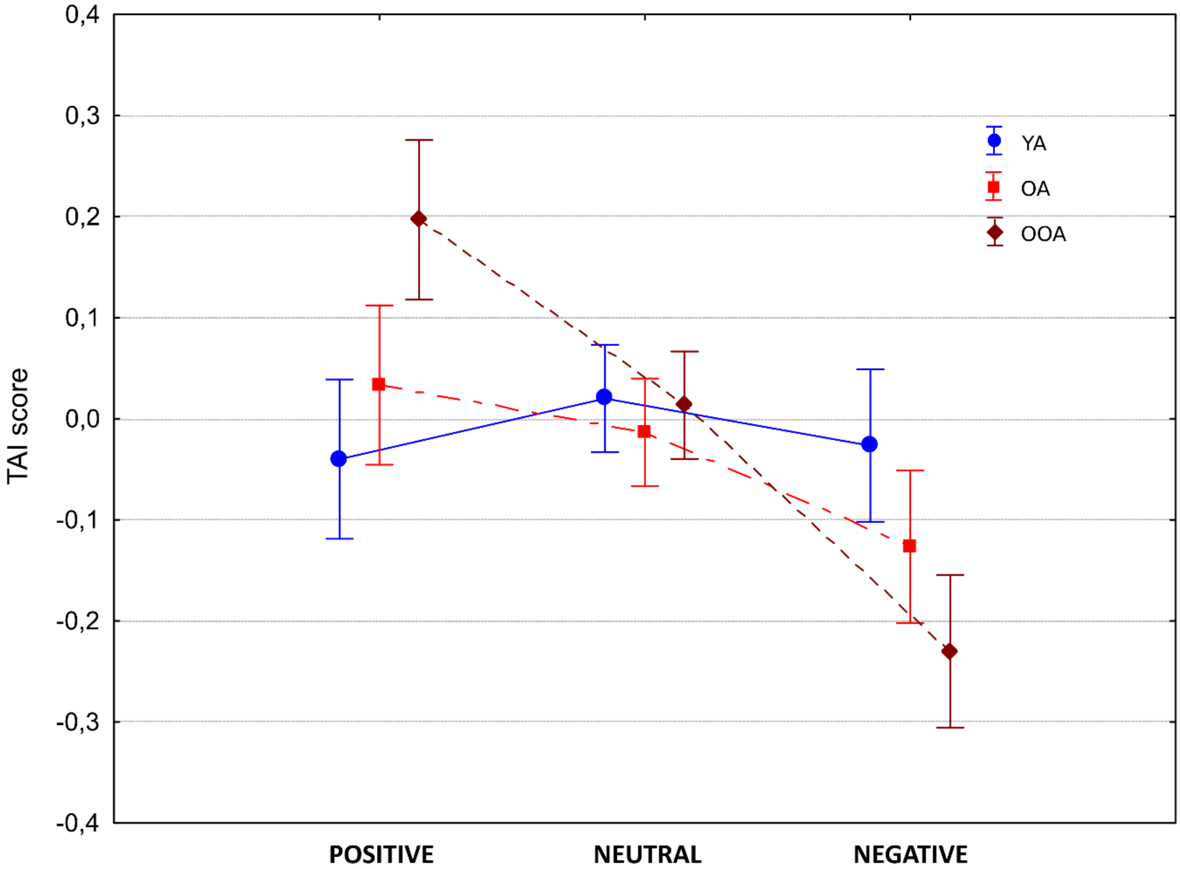
0,4
0,3
0,2
0,1
0,0
-0,1
-0,2
-0,3
-0,4
TAI score
YA
OA
OOA
POSITIVE
NEUTRAL
NEGATIVE

Figure captions

Figure 1. Experimental procedure.

Figure 2. TAI scores as a function of age groups and stimuli valence. 95% CI are shown.