

Aging and the subjective experience of time

Claudio Crisci¹ · Michelina Caccavale² · Luigi Trojano² 

Received: 10 April 2015 / Accepted: 17 June 2015
© Springer International Publishing Switzerland 2015

Abstract

Background The subjective experience of time involves several, not yet identified, mechanisms. Many cognitive and emotional factors, such as attention, memory and subjective mental states can influence time estimation.

Aims We aimed to assess the subjective experience of time and its relationships with cognitive and emotional characteristics in the elderly.

Method Forty-nine non-demented patients hospitalized for orthopedic rehabilitation underwent an ‘ecological’ evaluation tool, the semi-structured QUEstionnaire for the Subjective experience of Time (QUEST) requiring retrospective and prospective judgements on self-relevant time intervals. All patients completed tests to assess general cognitive functioning and two questionnaires to evaluate emotional state.

Results Results showed that accuracy in time estimation did not differ in young–old vs. old–old individuals: both groups performed better on prospective than on retrospective items and on highly than on poorly self-relevant items. Multiple regression analysis showed that performance on QUEST was significantly related to depression and hospitalization duration, but not to age, education, or neuropsychological scores.

Conclusions The influence of the emotional state is consistent with theories postulating that the “sense of time” is emergent from emotional and visceral states.

Keywords Time cognition · Ecological assessment · Elderly · Emotional state · Self-relevance

Introduction

Time cognition is a complex aspect of mind: time is intangible, there is no body organ responsible for its perception and subjective experience of time is not isometric to physical time [1]. As brain actively derives estimates of time from multiple sources of information, the “sense of time” can be considered as an emerging mental construct [2]. Recently, mental representation of space has been proposed as intimately linked to mental representation of time [3–5]. However, time cognition, and particularly the subjective experience of time, likely involves several cognitive and neural mechanisms, not yet fully identified [6]. Tasks and procedures used to investigate time processing are very variable, and this could explain divergences in empirical findings and theoretical models [7]. For this reason, widely shared terminology, commonly accepted procedures and clear operationalization are necessary for a better comprehension of time cognition [8]. Nevertheless, some agreement exists that factors such as attention, memory and subjective mental states can modulate time estimation [9, 10].

Studies assessing the effects of subjective mental states on time cognition suggest that normal subjects perceive time intervals as shorter than actual when they are engaged in pleasant activities [11]. On the contrary, emotional stress may induce overestimation of time intervals, likely contingent upon an attentional bias: subjects might focus their attention on time passing in order to avoid directing it on stressing events [12].

✉ Luigi Trojano
luigi.trojano@unina2.it

¹ Clinic Center Rehabilitation Institute, Naples, Italy

² Department of Psychology, Second University of Naples, Viale Ellittico 31, 81100 Caserta, Italy

Different theoretical frameworks are proposed to account for the effect of the above factors on time cognition. For instance, some models posit that a ‘central’ control mechanism (an ‘internal clock’) is involved in time processing and time judgements. Functioning of such an ‘internal clock’ would be influenced by attentional factors [13–15]. Other models, instead, foresee that subjective experience of time is an epiphenomenon of emotional and bodily states [16, 17]. Such a theoretical framework is related to the wider concept of embodied cognition, and accordingly it foresees time estimation to be modulated by many kinds of information (including interoceptive information) processed by the brain [18]. Recently, Wittmann [19] proposed the existence of a specific level of integration: the mental presence that sequentially maintains mental representations in an active state for a certain period of time, allowing the unified experience of presence. Within this framework, it has been shown that attention to interoceptive processes, likely mediated by the insula, can significantly affect subjective time experience [20].

A meta-analysis on the effect of aging on time cognition [21] demonstrated that older adults tend to provide larger verbal estimates than younger adults, whereas reproduction of duration would be unaffected by aging. More recently, Rammsayer [22] confirmed that the effect of age on time cognition can be selective: old adults are less efficient in discrimination of time periods lasting about 1 s than young adults; instead, reproduction of target durations and prospective estimation of time intervals appear to be unaffected by age (although older subjects tend to over-reproduce target durations). Most of these studies, however, employed experimental paradigms unconnected to common daily activities and assessed very short time durations (e.g., seconds). Indeed, many authors have underlined that older people might perform as well as younger subjects on tasks strictly relevant to their own daily activities [23]. In this perspective, it has been suggested that emotional relevance of stimuli might enhance task performance in the older people, if the task is concrete and realistic [24–27].

The aim of the present study was to assess cognitive and emotional subjects’ characteristics that can affect time experience in older patients without clinically relevant cognitive or neurological disturbances.

To the best of our knowledge, no specific test or questionnaire has been devised to specifically assess the subjective experience of time. Some tests of time estimation are indeed available, but they have been devised to tap the ability of making general cognitive inferences (e.g., by questions such as ‘In how long time will an egg become solid?’; [28]) rather than the subjective ‘time sense’.

To tackle time experience in the older people we devised a questionnaire specifically aimed to evaluate self-relevant, ecological time intervals. In particular, the questionnaire includes items assessing minute to daytime periods and implies retrospective and prospective judgements. Since this questionnaire is mainly aimed to evaluate time cognition in clinical samples of older patients, it foresees that subjects’ responses are checked by means of an informed caregiver or by clinical record. We administered such questionnaire, together with a short cognitive and emotional assessment battery, to a sample of cognitively unimpaired older people currently undergoing medical and physical rehabilitation.

Materials and methods

Subjects

We screened for the study a consecutive sample of older patients admitted to Clinic Center, Rehabilitation Institute, Naples, after a surgical intervention for implantation of artificial prostheses for hip fracture. Inclusion criteria for the study were as follows: at least 2 years of formal education and normal age- and education-adjusted scores on tests assessing general cognitive abilities (see below). Exclusion criteria were the following: present or past neurological or psychiatric diseases, severe pathological organ insufficiency (e.g., cardiac or renal failure, hepatic insufficiency) or severe neoplasms. Forty-nine subjects (41 females; mean age 78, range 65–94; mean education 7, range 2–18) met inclusion and exclusion criteria and gave their written informed consent to participate in the study. Eighteen patients (16 female) were aged 65–75 years, and the remaining patients (25 females) more than 75 years. The two groups did not differ significantly for years of formal education (t test = .175, p = .941).

Neuropsychological evaluation

All screened patients completed a short but wide-range screening battery of tests for general cognitive abilities (Mini Mental State Examination [29], Frontal Assessment Battery [30] and Clock Drawing Test [31]). All tests were administered according to Italian standardized procedures, and only patients who achieved age- and adjusted-scores within Italian normal ranges were enrolled for the study. Last, all enrolled patients completed two standardized questionnaires for assessment of anxiety and depressive symptoms (Hospital Anxiety and Depression Scale [32], Apathy Evaluation Scale [33]).

QUESTIONNAIRE for Subjective experience of Time (QUEST)

The QUEST is a questionnaire including 8 open-question items. The 8 items require performing estimations for relatively short (minutes) or long (days) time intervals; questions assess past or future events and are balanced for tapping highly or poorly self-relevant events (see “Appendix”). Subjects are required to provide estimation as accurate as possible for all items, and their responses are checked by means of an interview with an informed caregiver or referring to clinical records. For scoring purposes, we computed the difference between subject’s response and the ‘correct’ one for each item (positive values mean a trend to overestimation, negative values a trend to underestimation), and then we expressed each error as a percentage of the ‘correct’ response. A cumulative error index (CEI) is also computed, as the mean of absolute errors, i.e. regardless of their arithmetic sign.

Results

All patients completed the QUEST with no difficulty; mean administration time was about 9 min. Some instances of patients’ responses are enlisted in the “Appendix”.

A multivariate ANOVA on neuropsychological measures (Table 1) showed that the two groups of patients (young–old vs. old–old) differed significantly for Frontal Assessment Battery, $F(1,47) = 14.258$, $p < .001$, $\eta^2 = .195$, and Clock Drawing Test, $F(1,47) = 11.397$, $p = .001$, $\eta^2 = .233$, whereas the difference on Mini Mental State Examination only approached the Bonferroni-corrected significance level ($p < .008$), $F(1,47) = 7.35$, $p = .009$, $\eta^2 = .135$.

A mixed ANOVA on CEI, with age (young–old vs. old–old) as a between-group variable, and type of estimation

(retrospective vs. prospective) and self-relevance (high vs. low) as independent variables, revealed that age groups did not significantly affect the measure, $F(1,47) = 1.305$, $p = .259$, $\eta^2 = .027$ (see Table 1). By contrast, the effect of the two within-group variables was statistically significant. The effect of type of time estimation, $F(1,48) = 6.799$, $p = .012$, $\eta^2 = .117$, was due to larger errors with retrospective items (mean = .486, SD = .44, CI = .389–.567) than with prospective estimations (mean = .376, SD = .21, CI = .324–.410). The self-relevance effect, $F(1,48) = 81.399$, $p < .001$, $\eta^2 = .616$, was due to significantly larger errors with poorly self-relevant items (mean = .633, SD = .44, CI = .538–.716) than with highly self-relevant questions (mean .227, SD = .24, CI = .170–.267). The interaction between kind of estimation and self relevance was significant too, $F(1,48) = 5.894$, $p = .019$, $\eta^2 = .088$. Post-hoc comparisons, by means of Bonferroni tests corrected for multiple comparisons, revealed that errors were significantly larger for retrospective estimations than for prospective questions with highly self-relevant items, whereas retrospective and prospective estimations did not differ for poorly self-relevant items (see Table 2 for means, SD and 95 % confidence intervals for each measure). First- and second-order interactions including the variable age group were not statistically significant: $F(1,47) = .002$, $p = .968$, $\eta^2 = .001$, for kind of estimation X age group; $F(1,47) = .065$, $p = .800$, $\eta^2 = .001$, for self-relevance X age group; $F(1,47) = .614$, $p = .437$, $\eta^2 = .013$, for kind of estimation X self-relevance X age group.

A forward stepwise regression model, with CEI as the dependent variable and demographic characteristics (age, education and hospitalization duration) and neuropsychological scores (MMSE, FAB, HADS-anxiety, HADS-depression, Apathy Scale) as independent variables, showed that the first significant independent predictor of performance on QUEST was depression, $R^2 = .266$, $\beta = .516$,

Table 1 Demographic characteristics, raw neuropsychological scores

	All patients ($n = 49$)		Young-old ($n = 18$)		Old-old ($n = 31$)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	78.01	7.09	69.17	3.25	82.39	5.21
Formal education (years)	7.11	4.62	7.33	3.89	7.23	5.29
Hospital stay (days)	37.86	16.01	35.22	16.87	37.94	15.60
Neuropsychological measures						
Mini mental state examination	27.25	3.53	27.50	2.20	27.19	3.18
Clock drawing test	7.03	2.89	9.03	1.21	6.41*	2.63
Frontal assessment battery	11.96	3.18	14.00	2.30	11.23*	3.00
Apathy scale	32.90	6.62	31.67	6.85	33.10	6.09
HADS (anxiety score)	5.61	3.86	5.67	3.43	5.39	4.23
HADS (depression score)	3.07	2.76	2.11	1.67	3.42	3.02

* Significantly different from young-old (all $p < .008$, after Bonferroni correction)

Table 2 Mean percent error, SD and 95 % confidence intervals (CI) on the QUEstionnaire for Subjective experience of Time (QUEST) as a function of the type of item

	All patients (<i>n</i> = 49)			Young-old (<i>n</i> = 18)			Old-old (<i>n</i> = 31)		
	Mean	CI	SD	Mean	CI	SD	Mean	CI	SD
Retrospective, highly self-relevant items	.327	.233–.396	.274	.263	.135–.393	.266	.364	.266–.464	.276
Retrospective, poorly self-relevant items	.644	.500–.784	.472	.633	.407–.860	.444	.650	.478–.823	.495
Prospective, highly self-relevant items	.128	.082–.163	.136	.099	.035–.164	.100	.144	.096–.194	.152
Prospective, poorly self-relevant items	.622	.535–.689	.257	.572	.449–.694	.287	.652	.559–.754	.239
Cumulative error index (CEI)	3.667	3.142–4.191	1.874	3.362	2.471–4.254	1.557	3.844	3.165–4.523	2.03

Cumulative error index, i.e. the mean of errors regardless of their arithmetic sign, is also reported

$F = 13.797$, $p = .001$, with larger errors in patients with more severe depression symptoms. The second and last independent variable entered into the model was hospitalization duration (in days), $R^2 = .41$, $\beta = -.392$, $F = 13.235$, $p < .001$, $R_{\text{change}} = .151$, $p = .004$, with error decreasing with longer hospitalization.

Discussion

To assess time experience on self-relevant, ecologically valid items in older people we devised a new questionnaire, QUEST, proved to be simple to administer and easy to score. It revealed some interesting aspects of subjective experience of time in the older: participants made larger errors on retrospective judgements (with respect to judgements on future events) and on poorly self-relevant (with respect to highly self-relevant) items.

The higher accuracy for prospective judgements than for retrospective judgements would apparently contradict the well-known tendency of older patients to recall past events, the so-called reminiscence [34]. Reminiscence has been considered as an index of successful aging [35] and can be defined as the spontaneous recollection of past events, not linked to concrete situational requests. Instead, the retrospective judgements implied by the QUEST focused on specific aspects of time experience, determining larger errors with respect to prospective judgements. This phenomenon might be related to the established superiority of prospective judgements in normal subjects [36], in keeping with the recent observation that retrospective time estimation is crucially affected by emotional states [20]. It is also interesting to underline that the difference between accuracy in prospective and retrospective judgments might be compatible with recent theoretical models considering the mental representation of time connected with the mental representation of space [3, 4].

The significant effect of self-relevance (higher accuracy for highly than for poorly relevant items) would reinforce our idea that use of ecologically valid tools is the best

choice for assessment of time cognition in older people, as time perception in the older is thought to be strictly connected to emotional content [24, 25, 27]. This “emotional attention” seems even to enhance performance of older people, with respect to that of young, when adopting emotionally salient stimuli [26].

Involvement in pleasant activities tend to generate an underestimation of time passing [11, 20], whereas boring activities tend to produce a slowing of subjective experience of time [37]. It is possible that the effect of emotional saliency is related to different deployment of attentional resources [12] or that physiological states, and emotions associated with changes in physiological states, can influence subjective time estimates [20, 38]. Several studies attempted to disentangle the effects of attention and emotion [39, 40], but it would be interesting to investigate those effects or their interaction in older people [20]. The findings of the present study, addressing specifically the effect of self-relevance in older people, suggests that emotion-related factors can modulate subjective experience of time, but this issue needs to be explored further. It is worth mentioning, however, that the significant effect of self-relevance indirectly supports our assumption that evaluation of time cognition with self-relevant material can provide very different results from those obtained in experimental studies on time duration of neutral stimuli.

The specific relationship of time evaluation with emotional states is supported by the results of the stepwise regression: cumulative performance on QUEST was inversely related with presence of depressive symptoms, as previously observed with different paradigms [20, 41, 42]. In this perspective, the significant direct relationship between hospitalization duration and accuracy on QUEST might also be interpreted as due to the fact that early days of hospitalization are related with higher emotional stress.

The present correlation of subjective time experience with self-relevance and emotional state is consistent with findings reported in a study on patients with neoplastic diseases, in which there was a direct significant correlation between low quality of life and tendency to overestimate a

fixed time interval [42]. Taken together, evidence showing the effects of emotional states on time estimation abilities might support the ‘embodiment’ theoretical approach according to which time cognition is strictly related to emotional and bodily states [16–20, 38].

The lack of significant correlation between age and overall performance of older people on QUEST is compatible with the idea that aging has a little effect on time cognition when evaluation tools assess ecologically valid situations, whereas performance on unrealistic tasks clearly deteriorates in the elderly [23]. However, any generalization of our findings about the lack of deterioration of the time sense in the elderly should take into account that we only included in our study individuals from two age ranges (young–old, old–old) with relatively little age differences, that female participants were overrepresented and that our study sample might be too small to capture aging-related differences.

In conclusion, the present paper proposed a new, ecologically valid questionnaire to assess the subjective experience of time in the elderly. Despite the limitations of the study, use of emotionally salient stimuli demonstrated that the sense of time is strongly related to emotional and visceral states.

Compliance with ethical standards

Conflict of interest No author has any conflict of interest to disclose.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix

QUESTionnaire for Subjective experience of Time (QUEST)* including highly self-relevant (HR) and poorly self-relevant (PR), prospective (Pro) and retrospective (Ret) questions.

Item 1 (HR-Ret)-How long have you been staying in this Hospital?

Item 2 (HR-Ret)-How many days ago did you undergo surgery?

Item 3 (PR-Pro)-How long will you have to wait for your next meal?

Item 4 (PR-Ret)-How long did your physical therapy session last today (yesterday)?

Item 5 (HR-Pro)-Could you tell me how many days there are before next Christmas (Easter)?

Item 6 (HR-Pro)-In how long time will your relatives (friends) come to visit you?

Item 7 (PR-Ret)-How long has this interview lasted?

Item 8 (PR-Pro)-Could you drop a hint in 4 min?

Instances of participants’ responses.

Item 1: “...unfortunately I have to be there for much longer, I’m here only from 30 days...”.

Item 2: “...The operation, don’t make me think about, I was so scared, well, maybe 45 days have passed....”.

Item 3: “...I think in half an hour...”.

Item 4: “...well, I’d say 25 min, as it usually lasts...”.

Item 5: “...well, more or less 90 days, I’d say 90, this is the next event, I hope I’ll be well by then.

Item 6: “...I wait for them, I believe they will come in a couple of days...”.

Item 7: “...I think it lasted 10 min, a little more a little less, I would say that I have not noticed how much time elapsed...”.

Item 8: “...well, I would say now, I’m focusing on time and now I’m sure that 4 min have elapsed...”.

References

1. Wittmann M (2009) The inner experience of time. *Philos Trans R Soc Lond B Biol Sci* 364:1955–1967
2. Meck WH (2005) Neuropsychology of timing and time perception. *Brain Cogn* 58:1–8
3. Bonato M, Umiltà C (2014) Heterogeneous timescales are spatially represented. *Front Psychol* 5:542
4. Bonato M, Zorzi M, Umiltà C (2012) When time is space: evidence for a mental time line. *Neurosci Biobehav Rev* 36:2257–2273
5. Conson M, Cinque F, Barbarulo AM et al (2008) A common processing system for duration, order and spatial information: evidence from a time estimation task. *Exp Brain Res* 187:267–274
6. Page TL (1994) Time is the essence: molecular analysis of the biological clock. *Science* 263:1570–1573
7. Pande B, Pati AK (2010) Overestimation/underestimation of time: concept confusion hoodwink conclusion. *Biol Rhythm Res* 41:379–390
8. Coull JT, Nobre AC (2008) Dissociating explicit timing from temporal expectation with fMRI. *Curr Opin Neurobiol* 18:137–144
9. Block RA, Zakay D (2004) Prospective and retrospective duration judgments: an executive-control process. *Acta Neurobiol Exp (Wars)* 64:319–328
10. Taatgen NA, Rijn HV, Anderson JR (2007) An integrated theory of prospective time interval estimation: the role of cognition, attention and learning. *Psychol Rev* 114:577–598
11. Wittmann M, Lehnhoff S (2005) Age effects in the perception of time. *Psychol Rep* 97:921–935
12. Twenge JM, Catanese KR, Baumeister RF (2003) Social exclusion and the deconstructed state: time perception, meaninglessness, lethargy, lack of emotion, and self-awareness. *J Pers Soc Psychol* 85:409–423
13. Gibbon J, Church R (1984) Animal cognition: sources of variance in an information processing theory of timing. Erlbaum, London

14. Aschoff J (1998) Human perception of short and long time intervals: its correlation with body temperature and the duration of wake time. *J Biol Rhythm* 13:437–442
15. Pöppel E (2009) Pre-semantically defined temporal windows for cognitive processing. *Philos Trans R Soc Lond B Biol Sci* 364:1887–1896
16. Wittmann M, Simmons AN, Aron J et al (2010) Accumulation of neural activity in the posterior insula encodes the passage of time. *Neuropsychologia* 48:3110–3120
17. Wittmann M (2013) The inner sense of time: how the brain creates a representation of duration. *Nat Rev Neurosci* 14:217–223
18. Craig AD (2009) Emotional moments across time: a possible neural basis for time perception in the anterior insula. *Philos Trans R Soc Lond B Biol Sci* 364:1933–1942
19. Wittmann M (2011) Moments in time. *Front Integr Neurosci* 5:66
20. Pollatos O, Laubrock J, Wittmann M (2014) Interoceptive focus shapes the experience of time. *PLoS One* 9:e86934
21. Block RA, Zakay D, Hancock PA (1998) Human aging and duration judgments: a metaanalytic review. *Psychol Aging* 13:584–596
22. Rammsayer TH (2001) Ageing and temporal processing of durations within the psychological present. *Eur J Cogn Psychol* 13:549–565
23. Baltes PB, Baltes MM (1990) Psychological perspectives on successful aging: the model of selective optimization with compensation. In: Baltes PB, Baltes MM (eds) *Successful aging: perspectives from the behavioral sciences*, Cambridge University Press, New York, pp 1–34
24. Carstensen LL, Isaacowitz DM, Charles ST (1999) Taking time seriously: a theory of socioemotional selectivity. *Am Psychol* 54:165–181
25. Fung HH, Carstensen LL, Lutz AM (1999) Influence of time on social preferences: implications for life-span development. *Psychol Aging* 14:165–181
26. Fung HH, Carstensen LL (2003) Sending memorable messages to the old: age differences in preferences and memory for advertisements. *J Pers Soc Psychol* 85:163–178
27. Mather M, Canli T, English T et al (2004) Amygdala responses to emotionally valenced stimuli in older and younger adults. *Psychol Science* 15:259–263
28. Shallice T, Evans ME (1978) The involvement of the frontal lobes in cognitive estimation. *Cortex* 14:294–303
29. Measso G, Cavarzeran F, Zappalà G et al (1993) Mini Mental State Examination: a normative study on a random sample of Italian population. *Dev Neuropsychol* 9:77–85
30. Appollonio I, Leone M, Isella V et al (2005) The frontal assessment battery: normative values in an Italian population sample. *Neurol Sci* 26:108–116
31. O'Rourke N, Tuokko H, Hayden S et al (1997) Early identification of dementia: predictive validity of the clock test. *Arch Clin Neuropsychol* 12:257–267
32. Vedana L, Baiardi P, Sommaruga M et al (2002) Clinical validation of an anxiety and depression screening test for intensive in-hospital rehabilitation. *Monaldi Arch Chest Dis* 58:101–106
33. Marin RS, Biedrzycki RC, Firinciogullari S (1991) Reliability and validity of the Apathy Evaluation Scale. *Psychiatry Res* 38:143–162
34. Wong PT, Watt LM (1991) What types of reminiscence are associated with successful aging? *Psychol Aging* 6:272–279
35. Westerhof GJ, Bohlmeijer E, Webster JD (2010) Reminiscence and mental health: a review of recent progress in theory, research and interventions. *Ageing Soc* 30:697–721
36. Block RA, Zakay D (1997) Prospective and retrospective duration judgments: a meta-analytic review. *Psychon Bull Rev* 4:184–197
37. Bschor T, Ising M, Bauer M et al (2004) Time experience and time judgment in major depression, mania and healthy subjects. A controlled study of 93 subjects. *Acta Psychiatr Scand* 109:222–229
38. Wittmann M, Peter J, Gutina O et al (2014) Individual differences in self-attributed mindfulness levels are related to the experience of time and cognitive self-control. *Personal Individ Differ* 64:41–45
39. Angrilli A, Cherubini P, Pavese A et al (1997) The influence of affective factors on time perception. *Percept Psychophys* 59:972–982
40. Noulhiane M, Mella N, Samson S et al (2007) How emotional auditory stimuli modulate time perception. *Emotion* 7:697–704
41. Münzel K, Gender G, Steinberg R (1998) Time estimation of depressive patients: the influence of interval content. *Eur Arch Psychiatry Neurol Sci* 237:171–178
42. Wittmann M, Vollmer T, Schweiger C et al (2006) The relation between the experience of time and psychological distress in patients with hematological malignancies. *Palliat Support Care* 4:357–363