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Psychophysiology and Cognitive Functioning in Elderly: The Skin Conductance as a Reliable Marker of Memorization and Rememorization Capability

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Abstract

Objectives. The aim of the study is to assess the role of physiological activation in favoring the benefits of a series of sessions of reminiscence therapy (RT). **Methods.** Seven healthy elders (age: 87.7 ± 4.6) were recruited. A Psychophysiological Stress Profile (in three phases: baseline, stress, recovery) has been recorded in order to register the skin conductance (level and response, SCL-SCR). During the stress condition the Mini-Mental State Examination and Semantic Fluency Test were administered. The cognitive functioning was reassessed after seven sessions of RT. **Results.** On the basis of the SCR value (during stress condition), two groups have been made: high responders (HRs) and low responders (LRs). At baseline, HRs significantly differ in SCR (stress phase) and MMSE total score. After the RT, the same group reported higher scores in memory recall and lexical access. **Discussion.** A relation between physiological arousal and cognitive performance has been confirmed.

Keywords: autonomic nervous system; skin conductance; cognition; arousal; older people

Citation: Pruneti, C., Cosentino, C., & Guidotti, S. (2023). Psychophysiology and cognitive functioning in elderly: The skin conductance as a reliable marker of memorization and rememorization capability. *NeuroRegulation, 10*(1), 2–10. https://doi.org/10.15540/nr.10.1.2

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Introduction

The number of people aged above 65 years worldwide is increasing more and more, and it is estimated that it will reach 1.5 billion in 2050. Considering this assumption, healthy aging is becoming an important issue globally because of the increasing cost of healthcare (World Health Organization, 2011). Moreover, older adults' health status and health promotion issues are of critical concern because about one-fifth of older adults experience an age-related disorder with associated mental or physical disability. As a matter of fact, the most common neurological and psychopathological disorders in older adults are dementia, depression, anxiety, and substance abuse problems. In this scenario, health and social services, as well as long-term care for older adults, play important roles in promoting their mental health (World Health Organization, 2015; Yen & Lin, 2018).

According to recent estimates, older adults (> 65 years old) in long-term care are 5.3% in Australia (Australian Institute of Health and Welfare, 2012); 0.08% in Malaysia (Department of Statistics Malaysia, 2012); 3.9% in the United States of America (Jones et al., 2009); 4.1% in United Kingdom (Laing & Buisson, 2012); 3.2% in Germany (Molinuevo, 2008; Syed Elias et al., 2015), and 0.08% in Italy (Ministero della Salute, 2021). Although these percentages indicate only a small proportion of the population, the level and the type of care required is significantly demanding and challenging. Furthermore, this public issue will become even larger considering that the world population of older adults is increasing disproportionally (World Health Organization, 2012). Nevertheless, even considering the healthy aging, during this stage older adults find themselves having to cope with their feelings about life events (Erikson,

1959). For instance, adapting to the social environment, enjoying support, and being empowered to live and die with dignity are common topics (World Health Organization, 2015). Regarding this matter, reminiscence therapy (RT) generally helps older adults review their memories and past experiences, promoting a successful aging and the acceptance of death (Yen & Lin, 2018). In addition, RT demonstrated to benefit older patients with and without mental health problems (Syed Elias et al., 2015; Woods et al., 2005). Reminiscence, by definition, recalls past memories (Westerhof et al., 2010). More specifically, RT uses the recall of past events, feelings, and thoughts to facilitate pleasure, better quality of life, and better adjustment to present circumstances (Bulechek et al., 2008). Participants are free to discuss their life stories and they can focus on both pleasant and sad memories. Eight functions of RT were identified (Webster, 1993). Briefly, these were (1) identity and appreciating oneself; (2) problem solving and recognizing one's own strengths in dealing with problems; (3) death preparation and facilitating acceptance of death; (4) teach/inform and sharing life stories with the intent to teach; (5) conversation and developing ways of communication with other people; (6) bitterness revival and revisiting memories of difficult life events; (7) boredom reduction and reminiscing to relieve feelings of boredom; as well as (8) intimacy maintenance and remembering significant people. It was found that the eight functions of RT could be grouped according to three higher order dimensions linked to well-being: positive self-functions, negative self-functions, and prosocial functions. In summary, RT has (1) positive self-functions that are referred to preserving or developing self-awareness and included reminiscence for identity, problem solving, and death preparation; (2) negative self-functions that are related to regrets about the past and rumination and included bitterness revival, boredom reduction, and intimacy maintenance; and, (3) lastly, prosocial functions of reminiscence fostered relatedness with others such as conversation and teach/inform (Cappeliez et al., 2007; Cappeliez & Robitaille, 2010). For instance, describing negative feelings that were induced by a tragedy and then releasing the related grief with the support from the others may provide psychological relief for some individuals. In addition, although cognitive capacity may decrease also in healthy aging, cognitive performance can be stimulated by exercising memory systems and improving plasticity (Yen & Lin, 2018). Although some therapists prefer to use individual RT (Chong, 2000), when comparing it with group RT in long-term care, at least three authors preferred group RT since it encouraged social contact between the residents, enhanced communication skills, and established new relationships (Burnside & Haight, 1994; Roos & Malan, 2012; Zhou et al., 2012). Furthermore, a systematic review of RT for the treatment of depression established that the social role function of the group was the defining factor that made it more effective RT (Housden, 2009). Indeed, group RT usually comprises 6 to 10 participants in each therapy session to enhance group dynamics, whereas individual RT is conducted on a one-to-one basis (Chong, 2000). Because of its nonpharmacological nature, RT is usually used as an intervention for older adults in dementia care, long-term care, and hospice care (Cotelli et al., 2012). Moreover, given today's challenges in long-term care, this approach is valuable because it can be conducted during normal activities of daily life (i.e., during mealtime, walking around the facility; Klever, 2013).

Considering that the elderly population is increasing over time, it may be useful to identify the individual characteristics that make a person suitable for a specific nonpharmacological intervention. For instance, in the case of RT, the cognitive stimulation and the training of memory retention skills are supported by the emotional processing provoked by life events and related memories. Therefore, an emotional-psychophysiological activation is elicited in order to favor the re-elaboration of mnesic content. There are various studies that provide important information through the recording of psychophysiological parameters. More specifically, the literature is rich in studies that assessed the connection between emotional-psychophysiological arousal and cognition, but, to our knowledge, there is no research that investigated the role of the skin conductance (SC) (or galvanic skin response [GSR] or electrodermal activity [EDA]) as a reliable marker of cognitive efficiency and a predictor of the benefit obtained by a cognitive training in elderly subjects.

The hypothesis that drove the present study is based on the fact that the rapid phasic components of SC (the skin conductance response [SCR]) is the parameter that best reflects the phasic components of autonomic arousal (Fowles et al., 1981; Tranel & Damasio, 1984). More specifically, SCR has long been known as a sensitive index of psychosomatic arousal that is strictly connected to emotional activations, mental processing, and focused attention, especially considering stimuli with emotional or social valence (Bechara et al., 1996; Cacioppo et al., 2007; Gatti et al., 2018; Palomba et al., 2000; Pruneti et al., 2021). For instance,

previous studies demonstrated that SC, both during the rest phase (skin conductance level [SCL]) and during the stress presentation (SCR), is closely connected with the activation of specific brain areas responsible for processing the emotional value of a stimulus, such as the hypothalamus and amygdala (Gatti et al., 2018; Pruneti et al., 2021). Furthermore, other brain regions responsible for sustained and focal attention (i.e., prefrontal and orbito-frontal cortexes) emerged to be associated with autonomic activation (Pruneti et al., 2021). In summary, it is precisely for this reason that SCR is commonly considered by researchers as a good index of emotional and motivational involvement (Pennisi & Sarlo, 1998; Pribram & McGuinness, 1975). However, although these data are promising, only a few studies highlight the need for direct sympathetic autonomic activation to support the efficiency of these cognitive functions. The aim of this work was to confirm the association between neuropsychological and psychophysiological variables in a group of elderly subjects, selected according to the absence of serious neurodegenerative disorders. Considering the SCR as an index of emotional reactivity to create a group of high responders (HRs) to be compared with low responders (LRs), it has been hypothesized that HRs might benefit more from a series of RT sessions aimed at improving memory retrieval.

Materials and Methods

Study Design and Participants

In this exploratory and cross-sectional study, seven subjects aged between 82 and 94 years old (87.7 ± 4.6) were consecutively examined. The criteria for inclusion in the study were absence of neurodegenerative disorders or physical diseases; low-mild cognitive deficit assessed by the Short Portable Mental Status Questionnaire (SPMSQ; Pfeiffer, 1975); score less than 6 at the Geriatric Depression Scale (GDS; Yesavage et al., 1982); no assumption of psychoactive drugs.

Institutional Review Board Statement

This study was conducted in accordance with the recommendations of the local ethic committee at the University of Parma. In Italy, until 2018, no ethical approval was required for observational nature studies, since they were not defined as medical or clinical research, according to the Italian law No. 211/2003. The study was conducted before 2018 and included nonclinical surveys which used noninvasive measures. Furthermore, this study complies with the Declaration of Helsinki and with Italian privacy law (Legislative decree No. 196/2003). No treatments or false feedback were given, and no potentially harmful evaluation methods were used. Participation was voluntary, and participants could drop out at any time without any negative consequences. All data were stored only by using an anonymous ID for each participant and the data obtained were used solely for scientific purposes.

Procedures

The present research was developed in collaboration with a nursing home settled in Parma district (Azienda Pubblica di Servizi alla Persona, Parma), in which about 90 people with different characteristics live. Recruitment was done by two psychologists. In particular, a neuropsychological and psychophysiological assessment was made with devices and personnel from the Clinical Psychology, Clinical Psychophysiology, and Clinical Neuropsychology Labs at the University of Parma (Dept. of Medicine and Surgery), where all data were processed and analyzed.

For the first data collection, patients were taken to a quiet room and were informed by a research assistant about the study procedures. After providing informed consent, patients were administered the neuropsychological tests and were familiarized with the equipment (e.g., cables) and the procedure of the psychophysiological evaluation (see below). For the next 2 months, the selected patients received seven RT sessions. Lastly, for the second data collection, patients were readministered the neuropsychological tests.

Measures

The *Mini-Mental State Examination* (MMSE; Folstein et al., 1975) was used to assess overall general cognitive ability. The MMSE is a set of 11 questions that investigate five areas of cognitive functioning (orientation, immediate memory/recording, attention/concentration, delayed recall, and language). This instrument is currently the most widely used test for cognitive screening in clinical practice and is mentioned by several guidelines for the assessment of dementia and cognitive disorders. Indeed, it shows good sensitivity and reliability with Cronbach's α = 0.91 (Marioni et al., 2011).

The *Semantic Fluency Test* (SFT; Costa et al., 2014) was used to quantitatively assess the vocabulary. The subtest used by Costa and colleagues is a revised version of the test used by Novelli et al. (1986). In this version, the subject is asked to say as many words as possible belonging to the colors,

animals, and fruits categories in three different trials, which also lasted 60 s each.

The *Psychophysiological Stress Profile* (PSP; Cosentino et al., 2018; De Vincenzo et al., 2022; Fuller, 1979; Pruneti, Fontana, et al., 2011; Pruneti & Guidotti, 2022; Pruneti, Guidotti, et al., 2022; Pruneti, Lento, et al., 2010) structured in three phases was implemented. In the baseline phase (6 min), each participant was instructed to close their eyes and remain still and relaxed. During the stress phase (4 min), the participant was administered the neuropsychological tests (MMSE and SFT). Lastly, in the recovery phase (6 min) the participant was instructed to relax again. The SCL and SCR parameters were recorded giving a very low-intensity electrical direct current by means of two electrodes placed on the first and second fingers of the nondominant hand. More specifically, two gold plated electrodes were used. The employed technology device was the "psycholab VD 13" by SATEM (Rome, Italy). The Modulab was connected by means of an infrared cable with a PC and all the data was detected and processed by PC soft VD 13SV VERSION 5.0 Works program software by SATEM (Rome, Italy).

Statistical Analysis

Statistical analysis was performed using Microsoft Excel and IBM SPSS Statistics (Version 28.0.1.0). Differences between HR and LR participants with respect to neuropsychological and psychophysiological variables at baseline were assessed using the Mann-Whitney U Test. Considering the small sample size, a Spearman's Correlation was implemented to examine the association between the variables investigated. To test our hypothesis, another Mann Whitney U test was conducted in order to calculate statistical differences between the two groups on the neuropsychological test scores after the seven RT sessions. All statistics were considered significant if $p < 0.05$.

Results

All of the participants were males, married, and retired. The sample was divided in half considering the SCR value obtained during the stress condition of the PSP. The neuropsychological and psychophysiological features of the two groups of the sample are shown in Table 1 where differences at baseline between HR and LR are shown. Three participants were considered HRs while four participants were considered LRs. Considering the psychophysiological evaluation, HRs and LRs significantly differed only in the SCR value of the stress phase ($p < 0.03$). Moreover, HR participants reported higher scores on the MMSE ($p < 0.05$).

The associations between variables are reported in Table 2. The SCL recorded during the stress phase was negatively and moderately associated with both SCR stess ($p < 0.05$) and SCR recovery ($p < 0.05$) levels. Furthermore, SCR stress level was positively and moderately correlated with the total score of the MMSE ($p < 0.05$).

Lastly, the differences between HRs and LRs after the RT are shown in Table 3 where the comparison of the neuropsychological Lastly, the differences between HRs and LRs after the RT are shown in Table 3 where the comparison of the neuropsychological tests' scores between groups highlights significantly higher scores of recall ($p < 0.03$) and verbal fluency ($p < 0.03$) in HRs.

Discussion

The basic assumption underlying the present research was that psychophysiological arousal is strictly associated with cognitive efficiency. The aim of the present pilot study was to evaluate the possibility of dividing a group of healthy elderly people according to the parameter of the SCR in the mental stress condition and, therefore, to create a group of HR and a group of LR. More specifically, the difference between the two groups after cognitive training aimed at implementing memory recovery skills has been investigated.

Once the two groups, HR and LR, were created, significant differences in psychophysiological parameters and neuropsychological scores emerged. In particular, in the HR group, there are significantly higher values than the LR group both in the SCR (stress condition) and in the overall MMSE score. Moreover, it has emerged that the two variables are significantly associated, according to the Spearman's Correlation calculation. These data are in line with several previous studies that have shown that skin conductance reactivity correlates with mental performance (Cacioppo et al., 2007; Kim et al., 2019; Lim et al., 1996; Pruneti et al., 2021).

The second data collection served to investigate the hypothesis that guided the present research because the aim was to investigate the significant difference between the two groups after seven sessions of RT. To our knowledge, this aspect has never been investigated so far. However, it was hypothesized that subjects placed in the HR group

Table 1

Comparisons Of Neuropsychological and Psychophysiological Features Between High Responders and Low Responders During the First Data Collection.

	High Responders (*n* = 3)		Low Responders (*n* = 4)		*U*	*p*
	M	*SD*	*M*	*SD*		
Neuropsychological Assessment						
Mini-Mental State Examination						
Registration	1.67	1.5	1.75	1.3	3.0	0.18
Recall	3.00	0.0	2.50	0.6	6.0	1.00
Calculation	2.30	2.3	0.50	0.6	2.0	0.12
Total score	26.90	2.8	21.68	2.2	0.5	0.05
Semantic Fluency Test	22.00	5.6	19.00	5.0	3.5	0.37
Psychophysiological Assessment						
Skin Conductance Level						
Baseline	2.79	0.51	2.79	0.25	0.06	1.00
Stress	2.71	0.01	2.78	0.02	0.88	1.00
Recovery	2.80	0.05	2.79	0.01	1.56	0.43
Skin Conductance Response						
Baseline	2.75	0.66	2.80	1.00	1.22	0.49
Stress	6.87	0.27	2.47	1.18	7.00	0.03
Recovery	4.59	1.98	1.99	0.98	1.22	0.49

Table 2
Relationships Between Variables in the Whole Sample.

	1	2	3	4	5	6	7	8	9	10
1 SCL Baseline	1.00									
2 SCL Stress	0.38									
3 SCL Recovery	0.00	−0.12								
4 SCR Baseline	0.07	−0.09	0.58							
5 SCR Stress	−0.04	−0.85*	0.04	0.22						
6 SCR Recovery	−0.15	−0.78*	0.11	0.00	0.89					
7 MMSE Registration	0.10	0.10	−0.10	−0.10	0.28	0.38				
8 MMSE Recall	0.00	−0.33	0.00	−0.32	0.16	0.00	0.00			
9 MMSE Calculation	−0.25	−0.7	−0.3	−0.6	0.54	0.66	−0.05	0.35		
10 MMSE Total score	0.09	−0.71	−0.34	0.09	0.79*	0.49	0.00	0.40	0.48	
11 Semantic Fluency Test	−0.73	−0.67	−0.07	0.35	0.54	0.41	−0.05	−0.08	0.22	0.47

*$p < 0.05$. SCL = skin conductance level; SCR = skin conductance response; MMSE = Mini-Mental State Examination.

Table 3
Comparison of the Neuropsychological Tests Scores Between High Responders and Low Responders During the Second Data Collection.

	High Responders (n = 3)		Low Responders (n = 4)		U	p
	M	*SD*	*M*	*SD*		
Neuropsychological Assessment						
Mini-Mental State Examination						
Registration	3	0.0	1.00	0.82	6.0	0.03
Recall	3	0.0	3.00	0.00	0.0	1.00
Calculation	3	2.0	1.50	1.00	3.0	0.23
Semantic Fluency Test	31	5.2	21.25	4.60	0.0	0.03

could benefit most from cognitive training. This suggestion was confirmed because the subjects considered more reactive from a psychophysiological point of view reported higher scores in the MMSE subscale that investigates memory retrieval. Furthermore, the same subjects also appear to have improved their lexical access.

These data, although preliminary, allow to confirm what was repeatedly demonstrated about the relationship between cognition and arousal. The association of the measurement of skin conductance to cognitive performance has provided objective and quantitative features of emotional and motivational aspects that drive learning processes. Our results are in line with previous research that suggested that this parameter can be a sensitive and reliable measure of learning (Eisenstein, Bonheim, et al., 1995; Eisenstein, Eisenstein, et al., 1990). In addition, the present study shows that the SCR can be a good indicator of the level of cognitive efficiency even in a group of elderly people.

The close connection between arousal and mental efficiency confirms what was reported more than 100 years ago with the Yerkes-Dodson curve (Yerkes &

Dodson, 1908). According to this law, an optimal level of psychophysiological activation can facilitate the achievement of good results in terms of mental and physical performance. In fact, a low level of performance would be observable in both emotional hyperactivation and hypoactivation (Calabrese, 2008). Identifying the right level of physiological activation, which also involves stress management skills, is a useful aspect for many health professionals such as psychologists, neurologists, speech therapists, and physiotherapists, as well as teachers and educators. In fact, in clinical practice everyone knows that the level of activation, and, therefore, of motivation and collaboration, greatly influences the commitment, both mental and physical, and, thus, the performance. For instance, from the diagnostic to the rehabilitative fields, the optimal level of mental effort is fundamental in order to understand the real difficulties of the patients. Additional data, such as a measure of the emotional effort, can be derived within a psychophysiological evaluation which might be useful to test how difficult and complex is perceived the task administered to the subject examined. In fact, it is possible that low performance corresponds to a minimum level of effort (typical of manipulative and simulative attitudes but also indicative of serious impairment given by depression, for example) or a high effort (found in conditions of anxious hyperactivation or by real cognitive disorders present that cause distress). Furthermore, there are other practical implications of the present study considering the cognitive dimension.

Moreover, dysfunctional learning processes and memory retrieval are usually assessed through verbal tests that are cortically mediated and difficult to quantify. Nonverbal autonomic responses, like the SC, are mediated at a lower brain level, most probably the brain stem. Unlike verbal tests, the SC should be independent of language ability, education level, cultural background, intelligence quotient, and should be less subject to influence by experimenter-subject interaction. Furthermore, it can be quantified, and the subject is unaware of its occurrence or change over time. If cortical defects in learning and memory have autonomic correlates, then measures such as the SC may prove useful diagnostically in detecting a loss in learning and memory as a function of age and/or pathology at a very early stage when the loss may be more amenable to treatment. Its ability to be quantified at such a high level of measurement relative to verbal measures also may prove useful in the following progression of the loss as well as in assessing treatment efficacy. These aspects are often fundamental for a correct differential diagnosis.

However, conditions characterized by neurological and psychiatric disorders were excluded in our study. Thus, the different levels of stress response in terms of SCR can be read in terms of interindividual variability. Considering this, people who are more physiologically responsive are also easier to be emotionally engaged. This aspect could have effects on the effectiveness of an RT intervention which aims to stimulate cognitive functions by leveraging the ability to get excited by talking about personal life events.

Conclusion

These results, although preliminary, confirm the strong connection between cognition and psychophysiological activation, supporting the results of several previous studies (Gray et al., 2009; Logothetis et al., 2001; Pruneti & Boem, 1995; Pruneti et al., 2021).

To conclude, further studies with larger samples are certainly needed to confirm the preliminary data that emerged in this study. However, the results appear promising and future confirmations may also bring benefits in the clinical setting. In fact, carrying out a multidimensional assessment, which involves a psychophysiological assessment, could offer important suggestions to better interpret the dynamic balance of the person and their information processing systems, both tacitly and explicitly (Reda, 1988, 2016). These assumptions could therefore have repercussions both for the diagnostic and the intervention phases and even help decide what is the best treatment for that phase of that person's life.

Author Declarations

The authors declare no conflict of interest. This research received no external funding.

The data presented in this study are available upon reasonable request from the corresponding author.

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Received: November 23, 2022
Accepted: December 22, 2022
Published: March 30, 2023