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Breathing and affective picture processing across the adult lifespan

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ABSTRACT

The present study investigated differences between healthy younger, middle-aged, and older adults in their respiratory responses to pictures of different valence and arousal. Expiratory time shortened and end-tidal PCO_2 decreased with increasing arousal in all age groups; yet, compared to younger adults, older adults' overall change from baseline was smaller for expiratory time and larger for end-tidal PCO_2. Contrary to their younger counterparts, older adults' inspiratory time did not shorten with increasing arousal. Inspiratory duty cycle did not covary with affective ratings for younger adults, increased with unpleasantness for middle-aged adults, and increased with arousal for older adults. Thoracic breathing increased with increasing unpleasantness only among older adults. Age had no effects on mean inspiratory flow and minute ventilation, which both augmented as arousal increased. We discuss how age effects on respiratory response magnitude and pattern may depend on age-associated biological changes or reflect age-related differences in emotional processing.

1. Introduction

Much of what we know about our capacity to react to emotional events is based on studies with college-aged adults (Lench, Flores, & Bench, 2011). Few studies have examined how middle-aged and older adults react physiologically to affective stimuli under well-controlled laboratory conditions, and whether their reactions differ from those of younger adults.

The present study investigates age-related differences in the response behavior of breathing to series of affective pictures from a dimensional perspective of emotion. Breathing (dys)regulation has widespread physiological and psychological causes and effects (e.g., Courtney, 2009; Ramirez, 2014; Vlemincx, Abelson et al., 2013). However, psychophysiological investigations of affect include indices of respiratory activity less often than other physiological measures, and analyses are most of the time confined to respiratory rate (RR) and tidal volume (V_T) (Kreibig, 2010). RR and V_T provide only partial insight into the underlying mechanisms of respiratory control. A more detailed breathing analysis includes inspiratory time (T_I), expiratory time (T_E), total breath duration (T_{TOT}, the reciprocal of RR), inspiratory duty cycle (T_I/T_{TOT}), V_T, mean inspiratory flow (V_T/T_I), minute ventilation ($V'_E = RR \times V_T \sim V_T/T_I \times T_I/T_{TOT}$), and measures of the thoraco-abdominal balance such as the percent of rib cage contribution to V_I (%RC) (Boiten, Frijda, & Wientjes, 1994). V_T/T_I is considered to be an index of the intensity of the central inspiratory drive mechanism, which determines the intensity of the inspiratory stimulus, and T_I/T_{TOT} reflects the periodicity of the phase-switching mechanism, which initiates and terminates inspiration (Wientjes, 1992). Moreover, the partial pressure of carbon dioxide at the end of expiration ($P_{et}CO_2$) is an acceptable approximation of arterial PCO_2 values and an index of the equilibrium between ventilation and metabolic demands (Wilhelm, Alpers, Meuret, & Roth, 2001). If ventilation is too high in relation to the rate of CO_2 production (hyperventilation), arterial CO_2 and consequently $P_{et}CO_2$ fall.

The affective dimensions of valence and arousal define fundamental motive systems activated in response to stimuli, one appetitive, associated with positive valence and approach motivation, and the other defensive, associated with negative valence and aversive motivation. Arousal reflects the vigor of motivational mobilization (Bradley & Lang, 2007). In samples of young adults, skin conductance, heart rate, facial muscle activity, brain activity, and startle reflex eyeblink magnitude have been shown to covary with reports of valence and arousal (e.g., Bradley & Lang, 2007). Also breathing varies to some degree along valence and arousal. Overall, respiratory parameters seem to be more consistently related to the arousal dimension than the valence dimension; however,

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findings are complex and far from conclusive (Boiten et al., 1994; Boiten, 1998; Gomez & Danuser, 2004; Gomez, Shafy, & Danuser, 2008; Gomez, Stahel, & Danuser, 2004; Gomez, Zimmermann, Guttormsen-Schär, & Danuser, 2005; Hempel, Tulen, van Beveren, Mulder, & Hengeveld, 2007; Nyklicek, Thayer, & van Doornen, 1997; Ritz, Thons, Fahrenkrug, & Dahme, 2005; Van Diest et al., 2001; Vlemincx, Vigo, Vansteenwegen, Van den Bergh, & Van Diest, 2013).

We could locate five emotion studies in which age-related differences in RR or respiration depth were analyzed (Kunzmann & Grühn, 2005; Kunzmann, Kupperbusch, & Levenson, 2005; Overbeek, van Boxtel, & Westerink, 2012; Seider, Shiota, Whalen, & Levenson, 2011; Tsai, Levenson, & Carstensen, 2000). Only Tsai et al. (2000) reported an age effect, as older adults (ages 70–85 years) had lower RR than younger adults (ages 20–34 years) during an amusing film clip, but there were no age group differences during a sad film clip. According to these authors, these results may suggest that age-related changes in certain physiological responses may occur for certain emotions induced under specific conditions. To the best of our knowledge, no study on emotion and aging has provided detailed analyses of respiratory behavior as described above.

What seems to emerge from research on emotion and aging is that age-associated changes in physiological reactivity may not be unitary across contexts and measures. Within the limitations of cross-sectional designs, a number of laboratory-based studies provide evidence for age-related differences in cardiovascular reactivity (e.g., Burriss, Powell, & White, 2007; Kunzmann & Grühn, 2005; Overbeek et al., 2012; Seider et al., 2011; Smith, Hillman, & Duley, 2005; Tsai et al., 2000), electrodermal activity (e.g., Burriss et al., 2007), facial electromyographic activity (e.g., Smith et al., 2005), and brain activity (e.g., Kehoe, Toomey, Balsters, & Bokde, 2013; Mather et al., 2004; Smith et al., 2005). Compared to younger adults, older adults showed both blunted (e.g., Burriss et al., 2007; Mather et al., 2004; Smith et al., 2005; Tsai et al., 2000), augmented (e.g., Kunzmann & Grühn, 2005; Seider et al., 2011; Smith et al., 2005), and similar (e.g., Kunzmann & Richter, 2009; Kunzmann et al., 2005; Overbeek et al., 2012) physiological reactivity to affective challenges.

The respiratory system undergoes many changes with advancing age. These include modifications of the chest wall, the lungs, and the respiratory muscles resulting in reduction in chest wall compliance, decrease in strength of elastic recoil of lung parenchyma, enlargement of airspaces, changes in pulmonary vasculature, decrease in respiratory muscle strength, and reduction of lung function. Moreover, age-dependent differences exist in the ventilatory response to hypoxia, hypercapnia, added loading, and exercise (Lalley, 2013; Taylor, 2011). Breathing behavior depends on the interplay of different regulatory mechanisms, including reciprocal interactions between the pontomedullary respiratory network and numerous subcortical and cortical areas that are critically implicated in the generation of emotional states (Ramirez, 2014; Subramanian & Holstege, 2014). The brain activity to emotional stimuli of healthy younger and older adults is different, and these age-related differences appear to depend, to some extent, on the perceived valence and arousal tone of the stimuli (Dolcos, Katsumi, & Dixon, 2014; Kehoe et al., 2013; Nashiro Sakaki, & Mather, 2012). For instance, the amygdala activity to negative vs. positive information is reduced in older adults compared to younger adults, whereas unpleasant stimuli induce greater prefrontal cortex activity compared with neutral stimuli in older individuals than in younger ones (Nashiro et al., 2012). Also, older adults display different arousal-dependent responses than younger adults in a number of cortical regions (Kehoe et al., 2013). To the extent that the activity of brain structures involved both in emotion generation and breathing regulation changes in response to emotional challenges as age progresses, respiratory reactivity to affective stimuli may be expected to vary across ages.

The aim of the present study was to fill a gap in research on the psychophysiology of emotion and aging by examining age-related differences in the respiratory responses to affective pictures adopting the valence-arousal perspective as framework. Age effects on the physiological reactivity to emotional stimuli have been discussed in terms of age-associated differences in magnitude and pattern of physiological responding (Levenson, 2000). The design and analytical approach of the present study were set up in order to clarify whether age influences the "respiratory response magnitude", defined as the overall respiratory response to the stimuli in terms of magnitude of change from baseline (i.e., decrease/increase), and the "respiratory affective pattern", defined both as the pattern of breathing responses to specific affective categories (i.e., linear/quadratic trend across pleasant, neutral, unpleasant contents) and as the relationship between self-reported affective ratings and respiratory responses. Four main combinations of response magnitude and affective pattern are theoretically possible in terms of age effects, i.e., (i) Age groups do not differ either in their response magnitude or affective pattern; (ii) Age groups do not differ in their response magnitude but display different affective patterns; (iii) Age groups differ in their response magnitude but do not differ in their affective patterns; (iv) Age groups show differences both in their response magnitude and affective pattern. Taking V'_E as an example, an age effect on response magnitude would be that older adults show larger overall increases in V'_E from baseline than younger adults do. An example of age-related difference in the affective pattern would be that younger adults have larger changes in V'_E in response to pleasant and unpleasant vs. neutral contents and a significant negative correlation between V'_E changes and self-rated arousal, whereas older adults do not.

2. Method

2.1. Participants

The sample consisted of 176 participants in three age groups: younger (ages 20–34 years), middle-aged (ages 40–54 years), and older (ages 60–74 years). Studies of aging and emotion often compare young adults with an older sample. With the inclusion of a middle-aged sample nonlinear age effects can be explored. Table 1 reports other sample characteristics. Three additional participants completed the study protocol, but their data were unusable due to procedural flaws. Participants were recruited from the Lausanne area through advertisements placed in different public places, in newspapers and magazines, and on websites. The study was approved by the local ethics committee.

A screening questionnaire was used to include only respondents who: (i) were proficient in French; (ii) had scores lower than 11 on the anxiety and depression scales of the Hospital Anxiety Depression Scale (Zigmond & Snaith, 1983, 14 items, example items "I get sudden feelings of panic", "I still enjoy the things I used to enjoy", Anxiety and Depression scale min = 0, max = 21). This was done to avoid the experience of excessive emotional distress among vulnerable people; (iii) reported at least "satisfactory" current general health on a 5-point scale ranging from "very good" to "very bad"; (iv) were not pregnant or breastfeeding; (v) did not use recreational/illicit drugs; (vi) had normal or corrected-to-normal vision and did not suffer from color blindness; (vii) did not have a cardiac pacemaker; and (viii) were not currently under medical treatment for any psychiatric disorder.

Participants were well-functioning individuals as indicated by several indices (see Table 1). First, anxiety and depression scores were very low. Second, self-reported mental health, physical functioning, and general health perception as assessed with the Medical