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Temporal aspects of natural scene categorisation in healthy ageing

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A B S T R A C T

The visual system has an extraordinary capability to extract categorical information from complex scenes. Age-related deficits in visual temporal processing have been found with both low-level and high-level stimuli. However, it is unknown to which extent those deficits extend to the processing of complex scenes. Here, we investigated the temporal characteristics of natural scene categorisation in healthy ageing. Using a backward masking paradigm, we asked young-old (aged 59–70), old-old (aged 70+) and younger adults (18–31 years) to perform a go/no-go task, in which they had to respond to images of animals whilst ignoring images of landscapes. Both age groups were overall faster and more accurate in responding to the target images as the stimulus onset asynchrony (SOA) between target image and mask increased. Older adults, especially those in the old-old group, were significantly less accurate than younger adults for short SOAs but performed equally well at long SOAs. However, we found no age-difference in reaction times. Our findings suggest that the temporal processing of complex scenes is impaired in healthy older adults independently of reduced motor abilities. They also indicate that such deficits in natural scene categorisation become more evident with increasing age. Our findings might have important implications for the wellbeing of older adults and road safety in general.

1. Introduction

Healthy ageing in the absence of neurodegenerative diseases is accompanied by a variety of perceptual changes, including those related to vision (Andersen, 2012; Owsley, 2011). It has been well documented that many aspects of visual perception decline with healthy ageing, for example, vernier acuity (Pilz, Kunchulia, Parkosadze, & Herzog, 2015; Roinishvili, Chkonia, Stroux, Brand, & Herzog, 2011), spatial contrast sensitivity, (e.g., Owsley, Sekuler, & Siemsen, 1983; Elliott, Whitaker, & MacVeigh, 1990; Owsley, 2011), luminance processing (Sloane, Owsley, & Alvarez, 1988; Sloane, Owsley, & Jackson, 1988; Bieniek, Frei, & Rousselet, 2013; Schefrin, Tregear, Harvey, & Werner, 1999), or motion processing (Bennett, Sekuler, & Sekuler, 2007; Billino, Bremmer, & Gegenfurtner, 2008; Hutchinson, Arena, Allen, & Ledgeway, 2012; Norman, Ross, Hawkes, & Long, 2003; Roudaia, Bennett, Sekuler, & Pilz, 2010).

Age-related changes in motion perception have been found to be especially profound but the underlying mechanisms are up too now not very well understood. However, it has been suggested that age-related changes in motion perception are related to changes in the ability to integrate information across space and time, spatial and temporal processing, respectively (Roudaia et al., 2010). Roudaia et al., for example, tested age-related changes in apparent motion perception. They varied the inter-stimulus-interval between two successively presented frames of random-dots, and the spatial displacement between dots in both frames. Interestingly, they found that older adults performed less accurately than younger adults on large spatial displacements and long inter-stimulus intervals.

Another tool to study the timing of information processing in the visual system are visual masking paradigms. In such paradigms, the visibility of a target stimulus is reduced by the presentation of another spatially overlapping stimulus, the mask, which is presented in close temporal proximity to the target stimulus. Typically, the shorter the stimulus-onset-asynchrony (SOA) between the target and mask, the larger the masking effects. What is more, masking effects have been found to be more pronounced in older adults (Atchley & Hoffman, 2004; Pilz et al., 2015; Roinishvili et al., 2011). In fact, the hypothesis that older adults have difficulties with spatiotemporal integration was recently confirmed by studies that tested vernier acuity using the shine-through masking paradigm (Pilz et al., 2015; Roinishvili et al., 2011). Roinishvili et al. (2011) and Pilz et al. (2015) asked participants to indicate the offset direction of a vernier – two vertical bars of which the lower bar is either offset to the right or left compared to the upper bar. A masking grating comprising of aligned verniers was presented after the vernier and SOAs were measured – the time between

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vernier onset and grating. SOAs were largely increased for older compared to younger adults. Such increased SOAs suggest longer processing times for older adults, and indeed, using more complex masking gratings, Pilz et al. (2015) found large age-related deteriorations in spatial and temporal processing.

Age-related changes in visual temporal processing have also been found with other paradigms such as attentional blink (Lahar, Isaak, & McArthur, 2001) and rapid serial visual processing tasks (RSVP; Georgiou-Karistianis et al., 2007; Maciokas & Crognale, 2003; Lahar et al., 2001; Lee & Hsieh, 2009).

The studies cited above mainly test visual temporal processing related to lower-level visual abilities, i.e., vision relating to early visual processes including the processing of simple lines or motion pattern. However, recently a vast amount of research has concentrated on age-related changes in high-level temporal visual abilities. That is, higher-level visual stimuli with a closer relevance to real life such as natural scenes, faces, animals or objects. It has been shown that older adults have difficulties processing high-level visual information such as objects (e.g., Boutet & Faubert, 2006; Pilz, Konar, Vuong, Bennett, & Sekuler, 2011; Remy et al., 2013) and faces (e.g., Rousselet et al., 2009; Maguinness & Newell, 2014), or biological motion (e.g., Norman, Clayton, Shular & Thompson, 2004; Agnew, Phillips, & Pilz, 2016; Billino et al., 2008; Pilz, Bennett, & Sekuler, 2010). For biological motion stimuli, for example, it has been shown that older adults need longer presentation times to discriminate the walking direction (Pilz et al., 2010) or between different actions (Norman, Payton, Long, & Hawkes, 2004) or emotions (Spencer, Sekuler, Bennett, Giese, & Pilz, 2016) of point-light actions. However, the extent to which deficits in temporal processing affect the perception of more complex and relevant stimuli such as natural scenes is relatively unknown. To our knowledge, only one study has so far investigated natural scene processing in ageing, however, concentrating on spatial frequency processing rather than temporal processing changes. Ramanoël, Kauffmann, Cousin, Dojat, and Peyrin (2015) asked younger and older participants to perform a categorisation task (indoor vs. outdoor) on low and high spatial frequency scenes. Results showed that older adults categorised the scenes less rapidly than younger adults, but their performance only deteriorated when categorising high spatial frequency scenes.

The visual system has an extraordinary capability to extract categorical information from complex natural scenes (e.g., Johnson & Olshausen, 2003; Thorpe, Fize, & Marlot, 1996; Vanrullen & Thorpe, 2001). For example, participants are able to categorise the gist of a scene as a forest, beach or city in just a few milliseconds (e.g., Renninger & Malik, 2004; Schyns & Oliva, 1994), and are able to rapidly detect the presence of object categories such as faces, humans, animals or vehicles in briefly presented scenes (Rousselet, Macé, & Fabre-Thorpe, 2003; Thorpe et al., 1996; Vanrullen & Thorpe, 2001). The ability to rapidly detect the content and gist of a scene is very important in everyday life, because it allows us to quickly assess essential information. For example, when crossing the street, we need to be quickly aware of cars or cyclists, and when driving or cycling ourselves, it is important to quickly detect pedestrians that are about to cross the street.

As mentioned previously, temporal processing of older adults has been shown to decline, however scene perception is a temporal ability that has sparsely been investigated. Commonly, masking paradigms are used to study temporal processing of low-level, i.e., vernier acuity, but not high-level visual abilities. As an extension of this research, this study used a backward masking paradigm to assess the time course of visual processing of natural scene categorisation in older adults.

Bacon-Macé, Macé, Fabre-Thorpe, and Thorpe (2005), for example, used backwards masking to investigate the time course of visual processing in natural scene categorisation in younger adults. In their study, participants performed a go/no-go task, in which they had to respond to target images of animals whilst ignoring distractor images of landscapes. Bacon-Macé et al. (2005) found that visual processing on the high-level categorisation task was affected by masking, only at shorter SOAs (<25 ms). After 44 ms the mask had little effect on scene categorisation with participants exhibiting high accuracy levels. These results indicate that, except at very short SOAs, masking has relatively little effect on scene perception, thus highlighting the rapid and efficient nature of our human visual system at detecting and categorising scenes.

Previous studies have shown that age-effects are most prominent in adults older than 70 years of age (Hommel, Li, & Li, 2004; Potter, Grealy, Elliott, & Andrés, 2012; Trick & Enns, 1998). Therefore, to assess whether temporal processing of natural scenes differs across the older adult lifespan, we compared age-related changes in young-old (aged 59–70) and old-old (aged 70+) participants to performance of younger adults (aged < 31).

Using the same masking paradigm and procedure as Bacon-Macé et al. (2005), we investigated age differences in visual temporal processing of natural scene categorisation. We anticipated that the mask would have a much larger and longer lasting effect on older, particularly those aged 70+ years, compared to younger adults, similar to previous studies on temporal processing as described above. Deficits in the categorisation of natural scenes could have tremendous effects on older adults' quality of life and wellbeing, because such ability is required for so many daily tasks. Therefore, our results have important implications not only for the wellbeing of older adults, but also public safety.

2. Methods

2.1. Participants

41 younger participants (M = 20 years; SD = 1.8; Range = 18–31; 9 males), 19 young-old (M = 64 years; SD = 2.5; Range = 59–69; 5 males) and 14 old-old participants (M = 77 years; SD = 3.0; Range = 70–83; 2 males) took part in the experiment. Participants were recruited from the student population and the Psychology Participant panel of the University of Aberdeen. All participants were naive as to the purpose of the experiment and satisfied the following visual criteria: normal or corrected to normal visual acuity of at least 20/16 (measured by the ETDRS logarithmic vision chart), score within the normal range on the Pelli Robson Contrast Sensitivity test (1.5–2.00/2.5; Pelli & Robson, 1988), and no colour vision deficiency (measured by the City University Colour Vision test). Also, all older participants had visited an ophthalmologist or an optometrist within the past three years and were free of glaucoma, strabismus, amblyopia, macular degeneration or cataracts. Older participants completed the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), a screening measure for mild cognitive impairment. All participants' scores were within the normal range (range 26–30/30). Age-groups did not differ significantly in education years (younger: M = 13.8, young-old: M = 14.8, old-old: M = 15.1). Participants were reimbursed for their time with £5/hour or course credit. Informed consent was received from each participant. The experiment was approved by the local ethics committee and experiments were conducted in accordance with the Declaration of Helsinki.

2.2. Apparatus

The experiment was conducted on an Apple Mac Mini with MATLAB under the Psychtoolbox extension (Brainard, 1997; Pelli, 1997; Kleiner, Brainard, Pelli, Ingling, Murray & Broussard, 2007). Stimuli were presented on a 19 in CRT Dell monitor (model