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Research Report

Perceptual and cognitive neural correlates of the useful field of view test in older adults

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ABSTRACT

The Useful Field of View Test (UFOV) is often used as a behavioral assessment of age-related decline in visual perception and cognition. Poor performance may reflect slowed processing speed, difficulty dividing attention, and difficulty ignoring irrelevant information. However, the underlying neural correlates of UFOV performance have not been identified. The relationship between older adults' UFOV performance and event-related potential (ERP) components reflecting visual processing was examined. P1 amplitude increased with better UFOV performance involving object identification (subtest 1), suggesting that this task is associated with stimulus processing at an early perceptual level. Better performance in all UFOV subtests was associated with faster speed of processing, as reflected by decreases in P3b latency. Current evidence supports the hypothesis that the UFOV recruits both early perceptual and later cognitive processing involved in attentional control. The implications of these results are discussed.

1. Introduction

The Useful Field of View Test (UFOV) is a behavioral technique developed to measure age-related visual processing declines, which are not adequately assessed using standard clinical sensory measures (Ball and Owsley, 1993). The UFOV is a reliable and valid measure (Edwards et al., 2005a) that has been valuable in predicting the functional abilities of older adults, driving in particular (e.g., Clay et al., 2005). It is of further interest in that UFOV performance can be enhanced by training. Unlike most cognitive training approaches (Rabipour and Raz, 2012), UFOV training (a.k.a., cognitive speed of processing training) has numerous benefits among older adults including transfer to improved everyday functional performance (e.g., Ball et al., 2010; Edwards et al., 2005b; Roenker et al., 2003). We examined the underlying neural correlates of UFOV performance.

The UFOV was originally developed by Ball et al. (1988) to capture the visual processing difficulties of older adults to which standard sensory measures are not sensitive. Performance was initially conceptualized as visual sensory

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processing and defined as the extent of the visual field over which one can process information in a brief glance (Ball and Owsley, 1993). Subsequent research demonstrated that UFOV performance may also rely on cognitive capacity, speed of processing in particular (Clay et al., 2009; Lunsman et al., 2008; Owsley, 2013; Owsley et al., 1995). Evidence to date indicates that poor UFOV performance may reflect slowed processing speed, difficulty shifting attention, and difficulty ignoring irrelevant information (for a review, please see Owsley, 2013). Lunsman et al. (2008) provide evidence that the UFOV and the Digit Symbol Substitution Test (a traditional measure of cognitive speed of processing) show similar trajectories of age-related change, indicating that the two measures tap similar cognitive constructs. However, cognitive-behavioral measures rarely tap one cognitive construct in isolation and instead activate multiple cognitive functions. Indeed, UFOV performance may recruit multiple cognitive functions including executive functioning, processing speed, visuospatial ability, and various attentional mechanisms (for review, see Matas et al., 2014). Thus, while the UFOV is undoubtedly a useful tool to measure perceptual and cognitive abilities, there has been ongoing debate over the degree to which performance relies on perceptual vs. cognitive abilities, and over which cognitive abilities are involved (Ball et al., 2007; Lunsman et al., 2008). This has made it difficult to elucidate the underlying mechanisms of UFOV-related cognitive training gains and transfer. Therefore, the goal of the current study was to determine underlying neural correlates of UFOV performance.

To accomplish this goal, we correlated UFOV performance with event related potential (ERP) activity during a visual search task. To our knowledge, no prior studies have examined neural correlates of UFOV performance with ERPs, which allow for direct online observation of age-related deficits in cognitive capacity. While behavioral measures can provide useful information, they reflect combined effort stemming from several stages of processing (i.e., sensory, cognitive, and motor) and performance is influenced by extraneous factors (e.g., motivation, physical function), making it difficult to draw conclusions about the underlying series of neurophysiological processes. ERPs are reflective of ongoing brain activity and are particularly sensitive to the timing of mental processes (on the order of ms), such that early perceptual activity can be distinguished from post perceptual cognitive processes (Luck, 2012). Several ERP components have been identified as correlates of perceptual and cognitive processes using visual paradigms. In this study, we focused specifically on the P1, N1, P2, N2pc, and P3b components. We chose these components because they are elicited by the visual task used in this study and the mechanisms they represent have been linked to UFOV performance in past research using cognitive-behavioral techniques.

Beginning stages of stimulus processing are represented by the P1 and N1 components, which are generated in extrastriate visual cortex (Mangun et al., 1993). P1 and N1 are proposed to index early perceptual processing and are sensitive to attentional manipulations (Hillyard et al., 1998). Specifically, P1 has been shown to reflect early perceptual selection of a stimulus (Luck et al., 1990) and it is proposed to be an early index of the interaction between bottom-up perceptual processing and top-down attentional modulation of this processing (Hillyard et al., 1998). There has been recent evidence to suggest that P1 amplitude is smaller (Čeponienė et al., 2008; Finnigan et al., 2010; Gazzaley et al., 2008) and latency is longer (Čeponienė et al., 2008; Curran et al., 2001; Finnigan et al., 2010; Yordanova et al., 2004) in older adults, compared to younger adults, during visual choice tasks. N1 reflects exogenous orientation of attention to stimulus location (Luck et al., 1990). Evidence for the influence of age on N1 amplitude is discrepant. Both larger (Finnigan et al., 2010; Yordanova et al., 2004) and smaller (Čeponienė et al., 2008) amplitudes have been shown for older adults during various visual choice tasks. N1 latency appears to be longer with older age (Gazzaley et al., 2008), but this difference is not always significant (Čeponienė et al., 2008; Finnigan et al., 2010; Yordanova et al., 2004). By comparing the amplitude and latency of these components to UFOV performance, we are able to evaluate the involvement of the speed and intensity of early perceptual mechanisms, along with sensitivity to attentional demands, in the UFOV.

Components reflecting later endogenous stages of stimulus processing, such as P2, N2pc and P3b, are related to the cognitive processes of stimulus evaluation, selective attention, and conscious discrimination (Kok, 2000). Comparing the amplitude and latency of these components to UFOV performance will help elucidate the role of later cognitive processes in the UFOV. Specifically, the P2 component has been shown to index the encoding of visual features, particularly in working memory (Lefebvre et al., 2005; Wolach and Pratt, 2001), and is modulated by selective attention (Johannes et al., 1995). It is thought to generate from parietal occipital regions, and the posterior P2 has been shown to reflect feedback from higher visual areas (Kotsoni et al., 2007). Posterior P2 amplitude has both been shown to be age-invariant (Wood and Kisley, 2006) and smaller for older adults (Čeponienė et al., 2008; Finnigan et al., 2010), and it appears that P2 latency is also age-invariant (Čeponienė et al., 2008; Finnigan et al., 2010).

The N2pc component is likely derived from activity in the inferior temporal cortex (Luck and Hillyard, 1994b) and reflects the allocation of spatial attention to target selection through the suppression of distractors (Eimer, 1996; Luck and Hillyard, 1994b), with amplitude larger at posterior electrode sites contralateral to target location. N2pc has also been shown to have longer latencies and smaller amplitudes with age (Amenedo et al., 2012; orenzo-LóLpez et al., 2008).

The P3b component is closely associated with attention and the updating of working memory, originating from circuitry between frontal and temporal/parietal areas (Polich, 2003). P3b amplitude reflects the attentional processing of a target stimulus (for review see Polich (2007)), with larger amplitude to task-relevant infrequent stimuli, and P3b latency is reflective of cognitive processing speed (Donchin, 1981; Polich, 1996; Squires et al., 1977). P3b amplitude is reduced (Goodin et al., 1978; Pfefferbaum et al., 1980; Picton et al., 2000; Polich, 1997) and latency delayed (Gazzaley et al., 2008; Polich, 1997) in older adults.

ERPs were measured during a visual search task in which participants identified the presence or absence of an infrequently presented, vertically oriented target among an array of identical horizontally oriented stimuli. Targets were