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Neurodynamic correlates of response inhibition from emerging to mid adulthood

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ABSTRACT

Response inhibition, a key executive function, continues to develop in early adulthood in parallel with maturational processes of the underlying prefrontal regions known to support it. The current study examined behavioral and neurophysiological correlates of response inhibition during a visual Go/No-Go task in a large sample (N = 120) comprised of participants in their Early 20s (ages 19–21), Mid 20s (ages 23–27), and Early 30s (ages 28–42). The two younger groups had lower accuracy, shorter reaction times, and made more premature responses compared to Early 30s. These impulsive behavioral tendencies were reflected in a delayed N2 latency and reduced P2 and P3 amplitudes for Early 20s compared to Early 30s and were associated with personality traits such as impulsivity in an age-dependent manner. The results suggest that response inhibition may not develop fully before the approximate age of 25, as the refinement of the primarily prefrontal cognitive control network follows a protracted developmental trajectory throughout young adulthood.

1. Introduction

The ability to voluntarily control our behavior in a flexible and context-dependent manner is an important hallmark of the maturation of executive functions. Response inhibition is an essential capacity that allows individuals to actively suppress, interrupt, or delay an action (Aron, 2011). It plays an important role in everyday tasks such as withholding inappropriate responses or delaying their execution while gathering necessary information for completion (Schel, Ridderinkhof, & Crone, 2014). Compared to other higher-order functions, response inhibition is one of the last that develops, and one of the first to deteriorate with age (Hammerer, Li, Muller, & Lindenberger, 2010).

The Go/No-Go paradigm is commonly used to investigate response inhibition. It probes the ability to selectively inhibit a prepotent motor response on No-Go trials presented among the dominant Go (response activation) trials (Aron, 2011). In addition to response inhibition, this shift in the response pattern involves attentional capture due to high salience and low frequency of the No-Go stimuli (Tian, Shanshan, & Yao, 2014; Hampshire & Sharp, 2015). Performance on this task continues to linearly improve across childhood, adolescence, and into adulthood (Hammerer et al., 2010; Johnstone, Pleffer, Barry, Clarke, & Smith, 2005). FMRI studies show recruitment of right lateralized inhibitory network in adults (Aron, 2011),

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including dorsolateral prefrontal, inferior frontal and anterior cingulate cortices, as well as the pre-supplementary motor area. Neuroanatomical studies show substantial changes in these frontal areas through adolescence and young adulthood, primarily expressed in axonal myelination and gray matter pruning (Fjell et al., 2012; Schel et al., 2014; Sowell et al., 2003), with a reduction in cortical thickness and a simultaneous increase in white matter volume (Brown et al., 2012; Westlye et al., 2010). The gradual neuroanatomical development is accompanied by functional changes promoting efficient and fast recruitment of the inhibitory networks well into young adulthood. Using MEG with co-registered MRI, Vara, Pang, Vidal, Anagnostou, & Taylor (2014) compared spatiotemporal neural processes during a Go/No-Go task between adolescents (aged 13–17 years) and adults (aged 20–35 years) and found indications of an immature inhibitory control network in adolescence. Adults showed right dominant inferior frontal activity, while adolescents showed left dominant, bilateral activity in the inferior frontal regions, but also delayed recruitment of the left inferior frontal gyrus, prolonged recruitment of the right middle temporal gyrus and additional recruitment of the superior temporal gyrus compared to adults.

It can be expected that behavioral and structural developmental changes are reflected in electrophysiological indices. In the Go/No-Go task, early event-related potentials (ERPs) that arise during first 200 ms after the stimulus onset are the negative N1 and positive P2 deflections thought to reflect early perceptual effects (Albert, Lopez-Martin, Hinojosa, & Carretie, 2013; Bokura, Yamaguchi, & Kobayashi, 2001). The N2 deflection that occurs with a latency of 200–400 ms (Hammerer et al., 2010; Randall & Smith, 2011) has been estimated to originate in the lateral orbitofrontal and anterior cingulate cortex (Bokura et al., 2001; Huster, Enriquez-Geppert, Lavallee, Falkenstein, & Herrmann, 2013), and may reflect processes involved in stimulus evaluation and conflict monitoring (Donkers & van Boxtel, 2004; Enriquez-Geppert, Konrad, Pantev, & Huster, 2010; Huster et al., 2013). The P3 deflection occurs between 300 and 500 ms and is greater during salient stimuli requiring response inhibition/execution (Randall & Smith, 2011; Smith, Jamadar, Provost, & Michie, 2013). Its generators are estimated to a wider network including lateral orbitofrontal and anterior cingulate cortices, inferior parietal lobe and pre-supplementary motor area (Albert et al., 2013; Vara et al., 2014). Studies investigating neural mechanisms underlying inhibitory control in children and adolescents showed age-related decreases in frontal N2 and increases in frontal P3 amplitude concurrent with improved behavioral performance (Jonkman, 2006; Lamm, Zelazo, & Lewis, 2006). However, developmental studies of age-related changes in ERP components of response inhibition in young adulthood are scarce.

Young adulthood is a life period that begins in early 20s, and lasts through early 40s (Carter, Brandon, & Goldman, 2010; Courtney & Polich, 2009). It is marked by life-changing challenges like completing education, finding a full time job, leaving the parental household, and reaching financial independence. Response inhibition is particularly important at this age due to a tendency of young adults to engage in inappropriate behaviors (Crone & Ridderinkhof, 2011). The prevalence of risk-taking, impulsive behaviors, like substance abuse and risky driving at high speed or while intoxicated, peaks during early 20s (Doremus-Fitzwater, Varlinskaya, & Spear, 2010). In contrast to other periods of life, the leading cause of death in adolescence and early adulthood are accidents (World Life Expectancy, 2014), and the highest rates of binge-drinking episodes (consuming five or more alcoholic drinks on the same occasion) have been found among 18–25 year olds (Carter et al., 2010; Courtney & Polich, 2009). These behaviors are linked to impulsivity traits (Doremus-Fitzwater et al., 2010), and researchers agree that a tendency to risk-taking behavior is strongly related to the immature prefrontal cortex, which governs impulsivity, judgment, planning for the future, and foresight of possible consequences (Crone & Ridderinkhof, 2011; Vara et al., 2014).

Young adulthood is usually studied within a wide age range (from 20 to 40 years of age) making it very difficult to acquire a complete picture of response inhibition development, especially given that maturational changes are quite protracted during emerging adult years. The purpose of this study was to characterize the neural profile underlying response inhibition in young adults. Considering that successful inhibition requires rapid brain processes and that processing speed continuously changes over the adolescence and into emerging adult years, the temporal sensitivity of ERPs is critical for addressing this issue. Our aim was to investigate behavioral and neurophysiological differences in perceptual, decision making, or response inhibition processes across young adulthood, using a classical visual Go/No-Go task. We divided a large sample of young adults into three groups representing Early 20s, Mid 20s and Early 30s respectively. We hypothesized that response inhibitory control would be poorer in Early 20s, and would be reflected in lower performance accuracy, with N2 and P3 components indicating an immature inhibitory network. To the best of our knowledge, there are no other studies that have directly examined ERP correlates of response inhibition across young adulthood.

2. Material and methods

2.1. Participants

A total of 120 participants were included in the study, divided into three age groups: Early 20s, N = 40 (22 females), mean (±standard deviation), 19.9 (±0.8) years, age range 19–21 years, Mid 20s, N = 39 (20 females), 24.5 (±1.0) years, age range 23–27 years, and Early 30s, N = 41 (22 females), 33.2 (±3.9) years age range 28–42 years. An additional 13 participants took part in the study but were excluded because their ERP or behavioral data exceeded three standard deviations from the mean and were therefore categorized as outliers, and 5 others were excluded due to technical difficulties. All participants were right-handed, with normal or corrected-to-normal vision. None used any medication at the time of the study and none reported any previous head-injuries or had any EEG contraindications. They were recruited on a volunteer basis via E-mails, social networking (Facebook) and advertisements at the University of Zagreb. The study conformed to the 1964 Declaration