Clinical Neurophysiology 123 (2012) 2264–2272

Contents lists available at SciVerse ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Bandpass filter settings differentially affect measurement of P50 sensory gating in children and adults

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ARTICLE INFO

Article history:
Accepted 31 March 2012
Available online 18 May 2012

Keywords:
Children
Adults
Sensory gating
Event-related potentials
Signal-to-noise ratios

HIGHLIGHTS

- The present study aimed to determine the most appropriate filter setting to produce the smallest within group variance measures for analyzing the P50 gating data from neurotypical adults and typically developing children based on the findings of the P50 measures and the SNR.
- The results showed that 10–50 Hz filter setting may be optimal in studies that include only adults as these settings resulted in the smallest mean P50 T/C ratio, a reasonable standard deviation (*SD*) for the ratio, and the highest levels of SNR.
- However, the 10–200 Hz filter may be the best for studying young children as this setting had the smallest mean and *SD* of P50 T/C ratios for the child participants.

ABSTRACT

Objective: This study investigated the effect of four different bandpass filter settings on measures of the P50 component and the signal-to-noise ratios (SNR) of averaged ERPs obtained from a sensory gating paradigm employing paired-click stimuli.
Methods: Participants were adults ($n = 18$) 20–55 years old and children ($n = 25$) 5–10 years old who were free of neurological disorders.
Results: Results show that the filter settings (0.23–75 Hz, 10–50 Hz, 10–75 Hz, and 10–200 Hz) differentially affected the P50 amplitude, noise power and SNR measures of the conditioning and test clicks, and P50 T/C ratios.
Conclusions: The 10–50 Hz filter setting may be optimal in studies that include only adults as these settings resulted in the smallest mean P50 T/C ratio, a reasonable standard deviation (*SD*) for the ratio, and the highest SNRs. The 10–200 Hz filter may be the best for studying young children as this setting had the smallest mean and *SD* of P50 T/C ratios for these participants.
Significance: In studies that include both adults and children investigators are advised to use the 10–200 Hz filter setting because the smaller variability of sensory gating in the child group helps ensure better homogeneity of variance measures between the groups.

1. Introduction

Sensory gating has been conceptualized as the brain's natural response to attenuate irrelevant sensory stimuli (Freedman et al., 1987). This gating response is thought to be a critical underlying psychophysiological and protective mechanism of brain function (Myles-Worsley et al., 1996) which prevents sensory overload with subsequent cognitive disturbances (Clementz et al., 1997b). Traditionally, sensory gating is examined by the auditory P50 paired-click paradigm during electroencephalogram/event-related potential (EEG/ERP) recordings (Freedman et al., 1987). In this paired-click paradigm, the response at Cz to both the first click, (i.e., Conditioning click) and the second click (i.e., Test click) is measured as the positive deflection in the ERP about 40–80 ms post-stimulus onset and commonly labeled as "P50" (Freedman et al., 1987). The P50 T/C ratio, indicative of sensory gating, is the amplitude of the P50 of the Test (T) click divided by the P50 amplitude of the Conditioning (C) click (Freedman et al., 1987). Higher values of the P50 T/C ratio suggest a lower or diminished ability to inhibit

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http://dx.doi.org/10.1016/j.clinph.2012.03.019

irrelevant information (Boutrous and Belger, 1999; Cromwell et al., 2008).

Sensory gating has been studied for over 25 years (e.g., Adler et al., 1982; Hu et al., 2009; Lijffijt et al., 2009) and related to the cognitive functions of attention, working memory (Lijffijt et al., 2009; see Potter et al., 2006 for review), processing speed (Potter et al., 2006), and behavioral inhibition (Lijffijt et al., 2009). Given its importance in neurophysiological and/or neuropsychiatric research (e.g., schizophrenia, see de Wilde et al., 2007; Patterson et al., 2008 for review), issues regarding methodological analysis of sensory gating have been a concern (e.g., Light and Braff, 1998; Boutros, 2008; de Wilde et al., 2007; Patterson et al., 2008). Part of methodological concern of sensory gating stems from the P50 component itself. The P50 component is an evoked response with small amplitude varying from a fraction to a few microvolts (μV s), and this small amplitude makes the measurement of the P50 component susceptible to being influenced by the consequence of a low signal-to-noise ratio (SNR; Boutros, 2008). In the EEG recordings, low SNR can increase the variability for both measurements of spontaneous EEG activity and the stimulus-related evoked activity. This obscuring of the post-stimulus evoked response may give rise to misestimates of the strength of the evoked response (Hu et al., 2009). Adequate SNR is critical for reliable auditory evoked potential (EP) data (Turetsky et al., 1988).

The typical approach to offset effects of low SNR and improve on the reliability of the measurement of EP components is to have a large number of trials for inclusion in the averaging process of creating the EP (e.g., Boutros et al., 2009). However, this may not always be feasible as in the case of assessing individuals with neurological disorders or young children where the time these individuals may tolerate the EEG recording procedures can be limited. An alternate strategy is to use selective filter settings of the EEG signals to maximize the SNR of the component of interest. The accepted digital filter settings to study P50 sensory gating have changed across the past several decades (de Wilde et al., 2007; Freedman et al., 1998; Light and Braff, 1998; Patterson et al., 2008). Several studies have indicated that filter settings are critical in the P50 measurement and can affect quantification of T/C ratio (Freedman et al., 1998; Clementz and Blumenfeld, 2001; Patterson et al., 2008; Yvert et al., 2001). For example, Yvert et al. (2001) discovered that using a high-pass filter setting greater than 3.0 Hz could artificially augment the P50 amplitude. In addition, Patterson et al. (2008) found that the P50 T/C ratio was smaller at high-pass settings of 0.8 and 10 Hz, than at 30 Hz. Although Patterson et al. (2008) indicated that majority of P50 studies used a high-pass filter setting of 10 Hz to exploit P50 measurement, there is still a lack of agreement in the selection of the filter settings across studies (e.g., see both de Wilde et al., 2007 and Patterson et al., 2008 for review).

The choice of filter settings is not a trivial issue as Edgar and his colleagues have suggested that using inappropriate filter settings could lead to measurement errors in the EEG data (Edgar et al., 2005). For example, de Wilde et al. (2007) identified that filter settings were significantly correlated with the high variability of the P50 T/C ratio in schizophrenia studies. Thus, it is possible that filter settings are associated with the standard deviation (*SD*) of the P50 T/C ratios within experimental groups. In adult studies, Olincy et al. (2000) used the filter setting of 10–300 Hz and found that the *SD* of the T/C ratio was 0.12. Yee and White (2001) attained a *SD* of 0.34 of the T/C ratio when using the filter setting of 10–50 Hz. Kisley et al. (2004) observed that the *SD* of the T/C ratio was 0.25 with a filter setting of 10–75 Hz (Kisley et al., 2004), and Johannesen et al. (2005) obtained a *SD* of 0.33 of the T/C ratio with a filter setting of 0–50 Hz. With regard to child studies, Kemner and her colleagues used a filter setting of 0.1–200 Hz and observed that the *SD* of the T/C ratio was 0.36–0.50 (Kemner et al., 2002) whereas Marshall and his colleagues used a filter setting of 10–50 Hz and obtained an overall *SD* of 0.53 for the T/C ratio (Marshall et al., 2004). While these differences between standard deviations in these studies are likely to reflect variation in participant sample demographics moderated by differences in sample sizes, theoretically, differences in filter settings may also be a contributor.

Given the increasing use of the P50 sensory gating paradigm for studying various disorders besides schizophrenia in adults and children, such as traumatic brain injury (e.g., Arciniegas et al., 1999), attention-deficit/hyperactivity disorder (ADHD; e.g., Olincy et al., 2000), migraine (e.g., Ambrosini et al., 2001; Siniatchkin et al., 2003), autism (e.g., Kemner et al., 2002; Orekhova et al., 2008), centrotemporal spikes and sharp waves (CTS) associated with rolandic epilepsy (Fiedler et al., 2006), and sensory processing disorder (Davies et al., 2009), methodological issues of the SNR and filter settings need to be better addressed. Unfortunately, there is a paucity of empirical evidence for comparing the effects of various filter settings simultaneously on the P50 amplitudes to each click, the P50 T/C ratio, the SNR, and the within-group variability of the P50 for adults and no study has addressed these issues in children.

Therefore, the present study aims to address these issues. Based on the most frequently used filter settings found in the literature, the present study compares the differences between four different filter settings; 0.23–75 Hz, 10–50 Hz, 10–75 Hz, and 10–200 Hz. We hypothesized that filter settings would contribute to differences in the various measures of the P50 component and the SNR. The present study also aims to determine the most appropriate filter setting to produce the smallest within group variance measures for analyzing the P50 gating data from neurotypical adults and typically developing children based on the findings of the P50 measures and the SNR.

2. Method

2.1. Participants

This study was a retrospective analysis that included two groups of participants.[1] One group consisted of 18 adult volunteers (9 males & 9 females) between 20 and 55 years of age ($M = 33.28$; $SD = 11.35$), who reported no history of neurological, psychiatric or medical disorders. The other group comprised 25 typically developing children (13 males & 12 females) between 5 and 10 years of age ($M = 8.33$; $SD = 1.88$), who were free of neurological injuries, disabilities, and family histories of psychological disorders according to parent reports. This study was approved by the institutional review board of the local university. All adult participants completed an informed consent. For the child participants, both parent permission and child assent were obtained.

2.2. Procedure

The participants sat upright in a relaxed upright position in a high back chair during the EEG recording. Prior to the EEG recording, they received a short period of training on how to decrease muscle artifacts and eye blinks. All participants reported no hearing deficits and were given an auditory threshold screening before the presentation of the P50 sensory gating paradigm. For the details of the auditory threshold screening, please see Davies et al. (2009).

[1] The results of the P50 T/C ratio and amplitudes obtained from the filter setting at the 10–200 Hz in both the adult and the child groups were presented in the Davies et al. (2009) study. Also, the results of the P50 T/C ratios and amplitudes attained from the filter settings at the 0.23–75 Hz and the 10–75 Hz were presented in the 2007 annual conference of the Society for Psychophysiological Research (SPR).