Original Article, Critical Review

Documentation of Peripheral Auditory Function in Studies of the Auditory P300 Response: A Critical Review

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Abstract:

Objective: A critical review was conducted to examine whether the peripheral hearing status of participants with neurological and psychological disorders was documented in published clinical studies of the auditory P300 response.

Methods: Literature searches were conducted with 3 databases: PubMed, PsycINFO, and Scopus. Studies of participants with seven neurological or psychological disorders were included in the study. Each disorder was coupled with the main search phrase in separate searches on each database.

Results: Of the total 102 papers which met the inclusion criteria, the majority (64%) did not describe the peripheral hearing sensitivity of participants. In this review with studies that included participants at risk for hearing impairment, particularly age-related hearing loss, only a single publication adequately described formal hearing evaluation.

Conclusions: Peripheral hearing status is rarely defined in studies of the P300 response. The inclusion of participants with hearing loss likely affects the validity of findings for these studies. We recommend formal hearing assessment prior to inclusion of participants in studies of the auditory P300 response.

Significance: The findings of this study may increase the awareness among researchers outside the field of audiology of the effects of peripheral hearing loss on the auditory P300.

Keywords: Peripheral auditory function, auditory P300 response, event-related potentials, clinical application, neurological and psychological disorders

Conflict of Interest

None of the authors have potential conflicts of interest to be disclosed

Authorship

Janushca Author, data curation, formal analysis, investigation, methodology, project administration, writing – original draft; Leigh Author, supervision, writing – review & editing; Faheema Author, supervision, writing – review & editing; James Author, conceptualization, writing – review and editing.

All authors approved the final version of the article.

Open Data

The data that support the findings of this study are available on request from the corresponding author, Leigh Biagio de Jager.

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1. Introduction

The auditory P300 response is an electrophysiological cognitive measure (Polich, 2007). The P300 response is typically observed as a positive peak occurring approximately 300-ms after the presentation of a target auditory stimulus randomly presented among frequent, non-target, auditory stimuli in a test strategy referred to as the oddball paradigm (Picton, 1992; Polich, 2007). Latency of the auditory P300 response reflects auditory neural activity related to information discrimination and processing speed, whereas, amplitude reflects attention and working memory abilities (Polich, 1986; Polich & Heine, 1996).

For over 50 years, the auditory P300 response has widely been studied and applied clinically for a variety of neurological and psychological disorders, such as schizophrenia, dementia, Alzheimer's disease and depression (Cui et al., 2009; Frodl et al., 2002; Hall, 2015; Karaaslan et al., 2003; Pedroso et al., 2012; Picton, 1992). Research findings confirm differences in auditory P300 response amplitude and latency reported in individuals with these disorders (Polich, 1991; Polich, 2004; Roth & Cannon, 1972). For example, individuals with a diagnosis of schizophrenia typically yield reduced P300 amplitudes (Jeon & Polich, 2003). The auditory P300 response can also be applied as an objective measure of central auditory function in persons with suspected auditory processing disorder (APD) (Reis et al., 2015). Increased latency and decreased amplitude of the auditory P300 response in individuals with APD are associated with deficits in auditory attention, auditory memory, discrimination, integration and information processing (Jirsa & Clontz, 1990).

Multiple subject factors such as age, gender, peripheral hearing sensitivity, and certain medications may also influence the P300 response (Melynyte et al., 2018; Picton, 1992; Pollock & Schneider, 1992; Puttabasappa et al., 2017). There is evidence of larger P300 amplitudes in females versus males, likely due to hormonal and anatomical differences (Melynyte et al., 2018). Advancing age with age-related hearing impairment is also associated with prolonged latencies and reduced amplitudes (Pollock & Schneider, 1992). The effect of advanced age alone, on the auditory P300 response, shows an increase in latencies due to auditory maturation associated with advancing age in adults, while hearing loss causes an increase in latency and a decrease in amplitude (Puttabasappa et al., 2017; Reis et al., 2015). Degree of hearing loss is also a factor in auditory P300 measurements (Reis et al., 2015). Although the auditory P300 response is typically not applied clinically in the assessment of peripheral auditory status, hearing sensitivity does affect P300 recordings (Picton, 1992).

Peripheral hearing loss may compromise clinical application of the P300 response in patients with neurological and psychological diseases and disorders. Hearing loss is not uncommon in participants in P300 studies. Studies focusing on disorders such as Alzheimer's disease and dementia often include elderly participants (Ralli et al., 2019). Target populations that are at risk for age-related hearing loss (Fjell & Walhovd, 2003). According to the World Health Organization, a disabling hearing loss is expected in an estimated 25% of persons over 60 years of age (World Health Organization, 2019). Recent studies have also shown that adults with hearing loss are at higher risk for developing dementia (Brewster et al., 2021; Loughrey et al., 2018; Thomson et al., 2017). Age-related hearing impairment is characterized by a gradual decrease in high-frequency hearing thresholds (Gates & Mills, 2005; Hall, 2014; Rigters et al., 2019; Salvi et al., 2018). High-frequency stimuli often used to elicit the auditory P300 response (Picton, 1992; Polich et al., 1996), increase the likelihood of age-related hearing impairment impacting the outcome of P300 response measurements. Failure to document and account for hearing sensitivity in participants of P300 studies may influence data analysis and even compromise the conclusions of studies.

We critically review publications describing auditory P300 findings in persons with neurological and psychological disorders to determine whether the hearing sensitivity of participants was formally evaluated, adequately described, and documented in the methods section of the papers.

2. Method

2.1 Research design

A critical review was conducted through the review of published studies relating to the auditory P300 response being applied clinically for neurological and psychological disorders, to investigate whether the peripheral hearing status of participants was accounted for and documented. A critical review aims to comprehensively research literature to critically review its quality (Grant & Booth, 2009).

2.2 Literature search strategy

PubMed, PsycINFO and Scopus were searched to identify studies that met the inclusion criteria. Pubmed was searched using available Medical Subject Headings (MeSH) terms. As seven disorders were included in the study, each disorder was coupled with the main search phrase (‘auditory P300’) in separate searches on each database (e.g. ‘auditory P300 response’ AND ‘schizophrenia’). A total of 21 searches were conducted across each one of the three databases (Table 1). The initial search resulted in a total of 278 articles.

2.3 Inclusion and exclusion criteria

The inclusion criteria were: 1) peer-reviewed published studies of the auditory P300 response used as a biomarker for selected psychological and neurological disorders, as a measurement of treatment progress, or as a predictor of genetic risk for such disorders; 2) study participants with disorders including schizophrenia, dementia, Alzheimer’s disease, bipolar disorder, depressive disorder, traumatic brain injury, and auditory processing disorder. A pilot study with a review of literature published from 1990 to 2019 was conducted in 2019. The search terms consisted of the ‘auditory P300 response’ in combination with 25 different disorders, to identify the most frequently occurring disorders in literature. The seven disorders with the most published literature available at that time were, therefore, included in the review; 3)

English-language articles, and 4) articles published from 2000 to 2020. Our last literature search was conducted in August 2020.

Table 1. Databases and search strategies utilized

	Search strategy	Seven phrases	Limiters	Number of articles
PsycINFO	Terms occurring in all fields	"auditory P300" AND "schizophrenia" "auditory P300" AND "dementia" "auditory P300" AND "Alzheimer's disease" "auditory P300" AND "depression" "auditory P300" AND "bipolar disorder" "auditory P300" AND "traumatic brain injury" "auditory P300" AND "auditory processing disorder"	English journal articles published from 2000 to 2019	84
PubMed	MeSH terms relating to specific disorders and terms occurring in all fields		English journal articles published from 2000 to 2019	96
Scopus	Terms occurring in all fields		English peer-reviewed journal articles published from 2000 to 2019	98

Exclusion criteria were: 1) non-English-language publications; 2) publications that were not peer-reviewed; 3) papers describing studies of the visual P300 response but not the auditory P300 response; 4) non-clinical (animal) studies; 5) review articles; 6) pilot or preliminary studies, and; 7) papers that did not describe amplitude and latency data for the P300 recordings.

2.4 Study selection

After the initial search, the titles of all articles were reviewed and duplicate articles were removed (Figure 1). Abstracts of the remaining 67 articles were reviewed, resulting in the exclusion of an additional 15 articles that did not meet the inclusion criteria, or for which we could not obtain the entire article. The full text of the remaining 52 articles was then reviewed, of which a further six articles were excluded due to not completely meeting the inclusion or exclusion criteria.

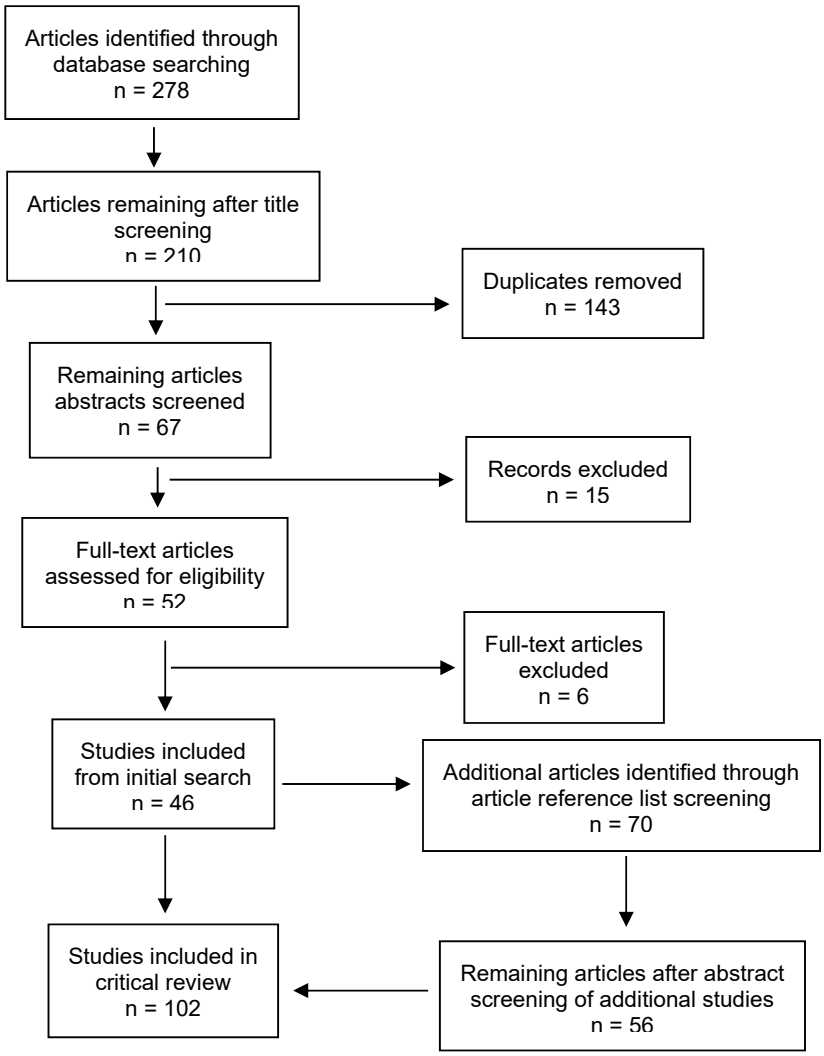

Figure 1. Data collection process

A secondary search strategy was then conducted by reviewing the reference lists of the remaining 46 articles from the initial search to ensure that all existing literature was considered. A total of 56 additional articles were identified and added, resulting in a total of 102 articles that were included in the review. To avoid selection bias, search strategies were established in advance. The first author reviewed the full text of all remaining articles, and any discrepancies were highlighted. The discrepancies were discussed among authors. Articles were included in the final selection only if a consensus was reached between three of the authors.

2.5 Data extraction and analysis

DistillerSR, a literature review software program, was utilized to aid in data extraction and analysis. Data extraction was completed with a close review of all selected publications. Quantitative data was collected from each study. Descriptive data analysis was used to organize and analyze data collected from each study.

3. Results

3.1 Characteristics

Of the total 102 studies included in the review, 61% were published over the decade 2000 to 2009, whereas 39% were published from 2010 to 2020. Participant ages across the studies ranged from 8 to 90 years. Two studies included participants younger than 18 years of age, and 43 studies (42%) included some participants above the age of 50 years. The number of participants varied across studies with the lowest being an N of 10 and the highest an N of 1790 participants. Most studies (93%) included both male and female participants, with 7% male-only participants studies.

All but one of the studies (99%) were published in psychology, psychiatry, or neurology-related journals. The one exception, a study of the P300 response in participants with APD, was published in an audiology journal. Three main study themes were identified across studies (Figure 2).

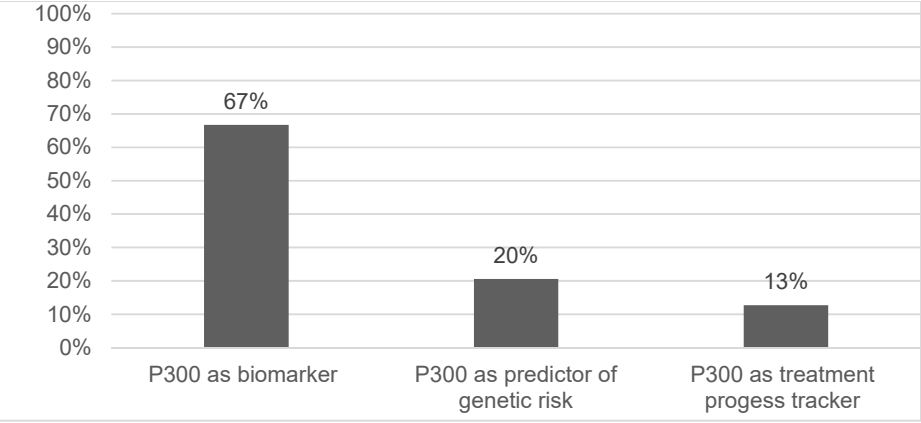

Figure 2. Main themes regarding the auditory P300 identified (n = 102)

Papers included in the review reported P300 findings for seven disorders included in the initial database search or combinations of these disorders. The distribution of disorders investigated across studies is presented in Table 2.

Table 2. Different disorders investigated across included studies (n = 102)

Disorder(s) investigated	Percentage of studies
Schizophrenia	60%
Psychosis	14%
Alzheimer's disease/Dementia	5%
Bipolar disorder	5%
Depression	4%
Schizophrenia and psychosis	4%
Psychosis and depression	2%
Schizophrenia and bipolar disorder	2%
Schizophrenia and Alzheimer's disease	1%
Psychosis and bipolar disorder	1%
Bipolar depression	1%
Auditory processing disorder	1%

The two most prevalent disorders investigated across included studies were schizophrenia, psychosis, or a combination of both these disorders (n = 80; 78%). In addition to the auditory P300 response, 43% of studies (n = 44) also included other types of electrophysiological assessments, such as the N100, N200 and P200 components, as well as the visual P300 response.

3.2 Description of peripheral auditory status of participants

Most studies did not describe participant peripheral hearing status, such as hearing sensitivity (64%; n = 65). Among papers that did mention peripheral hearing status, the methods used to assess hearing differed considerably (Figure 3).

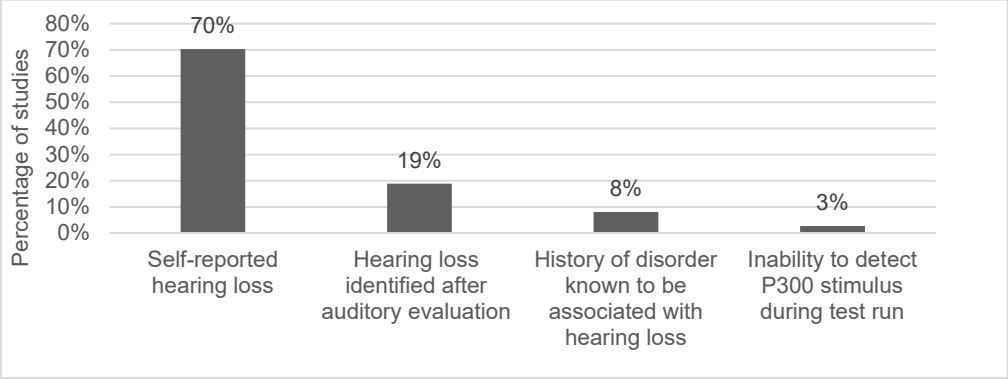

Figure 3. Criteria utilized regarding peripheral hearing status of participants (n = 37)

Of the 37 studies (36%) that did account for hearing sensitivity, most (70%; n = 26) excluded participants based on self-reported hearing loss. However, only two of these studies (8%) described the degree of self-reported hearing loss that warranted the exclusion of participants. Of the studies that excluded participants based on self-reported hearing loss, four (15%) indicated that only 'normal hearing' participants were included, whereas 22 studies (85%) excluded participants who reported hearing impairments. Of the total number of studies that considered hearing sensitivity, three studies excluded participants based on the presence of other unspecified physical disorders associated with hearing loss, and one study excluded participants who could not perceive the auditory P300 stimulus tone during a trial run of the assessment.

Of all the articles reviewed, seven papers (7%) described the evaluation of peripheral hearing sensitivity of participants. However, among these seven papers, only one specified that a comprehensive audiological assessment was conducted to identify participants with hearing impairment. One paper reported that a 500 Hz tuning fork was employed to test hearing. The remaining five papers failed to mention how hearing status was assessed.

Another study conducted two experiments, with two different participant groups. Peripheral hearing sensitivity was noted only for participants in the first experiment. Finally, the authors of one paper among those included in the review acknowledged

that the failure to assess peripheral hearing sensitivity was a limitation of their study (Iwanami et al., 2002).

3.3 P300 frequency and stimulus intensity

Most papers (96%) described the intensity levels of stimuli used to elicit the auditory P300 response stimulus. One paper indicated that normal hearing sensitivity was confirmed with '1000 kHz' tones (Light et al., 2015). This is presumably a typographical error or an error in terminology because 1000 kHz is a frequency of 1,000,000 Hz. Four papers included in the review failed to describe the intensity level of the stimuli used to elicit the auditory P300 response. The authors of one paper apparently erroneously indicated that the stimulus intensity was at 480 dB. Six other papers stated that the stimuli were presented somewhere within the range of 43 to 75 dB referenced to the participant's subjective hearing threshold for the stimulus. All papers that specified P300 test parameters reported stimulus intensity levels between 55 to 90 dB. The majority of studies (59%) presented P300 target stimulus of 1000 or 2000 Hz and non-target stimuli of 1500 and 1000 Hz. The remaining studies utilized other (rare) target versus frequent (non-target) frequency combinations, whereas 3% of studies provided no details on stimulus frequency.

3.4 Participant age and hearing sensitivity

Almost two-thirds of the studies (64%) that did not account for hearing sensitivity included participants at risk for age-related hearing loss, namely participants above 50 years of age. Table 3 summarizes age and hearing status, and the stimulus parameters of frequency and intensity for studies that included participants aged 50 years and older.

Among studies that included participants 50 years of age and older, three (7%) elicited the auditory P300 response with stimuli 43 or 50 dB above the participants' subjective hearing threshold but did not evaluate participant hearing status. Thirty-three studies (77%) utilized target (rare) stimuli presented at a higher frequency than the non-target (frequent) stimulus. Some of these studies (n = 16) also included one or more stimuli at a frequency of 2000 Hz or higher. None of the papers listed hearing status as a factor in the analysis of P300 recordings.

Table 3. Audiometric documentation in studies that included participants 50 years of age and older

Author(s) & year	Number of Participants	Age Range (yrs.)	Mean Age	Documentation of Hearing Status	Stimulus Intensity (dB)	Stimulus Frequency (Hz)
Bachiller et al., 2015	69	Not indicated	T group: 40.37; C group: 33.65	No mention of hearing status	90	T: 500, NT: 2000
Bestelmeyer et al., 2009	E1: 27 twin pairs; E2: 75	Not indicated	E1: T group (MZ twins): 34.1; T group (DZ twins): 33.8; E2: T group (SZ): 41.5; T group (BPD): 49.5; C group: 37.4	E1: Excluded participants based on self–reported hearing impairment	70	T: 2000, NT: 1000
Bonanni et al., 2010	119	Not indicated	T group (AD): 71.7; T group (DLB): 69.9; C group: 72.0	No mention of hearing status	75	T: 500, NT: 1000
Bramon et al., 2005	110	T group: 25 - 56; T group (relatives): 18 - 70; C: 18 - 70	T group: 35.8; T group (relatives): 51.0; C group: 42.4	No mention of hearing status	80	T: 1500, NT: 1000
Chang et al., 2006	38	45 - 63	T group: 57,3	Excluded participants based on self–reported hearing impairment	80	T: 2000, NT: 750
Decoster et al., 2012	332	14.4 – 64.2	T group: 32.4	No mention of hearing status	70	T: 1470, NT: 800
Ford et al., 2001	78	19 - 63	T group (SZ): 37.3; T group (epilepsy with SZ): 34.7; T group (epilepsy without SZ): 41.4; C group: 38	No mention of hearing status	80	T: 1000, NT: 500
Ford et al., 2008	43	Not indicated	T group: 39.19; C group: 37.29	No mention of hearing status	80	T: 1000, NT: 500
Hall et al., 2007	94 twin pairs	Not indicated	T group (twins - discordant): 41. 8; T group (twins - concordant): 40. 3; C group (MZ): 33. 3;C group (DZ): 40. 2	Excluded participants based on self–reported hearing impairment	43 above threshold	T: 1500, NT: 1000
Hall et al., 2007	25 twin pairs; 77 other	T group (twins - concordant): 23 - 64; T group (twins - discordant): 23 - 52; C group (MZ): 19 - 56; C group (DZ): 20 - 58	T group (twins - concordant): 41.5; T group (twins = discordant): 31.6; C group (MZ): 33.1; C group (DZ): 40.2	Excluded participants based on self–reported hearing impairment	43 above threshold	T: 1500, NT: 1000
Hall et al., 2009	94 twin pairs; 70 other	Not indicated	T group (BPD): 42.34; T group (parents): 43.31; T group (siblings): 42.84; C group: 37.14	Excluded participants based on self–reported hearing impairment	80	T: 1500, NT: 1000
Iwanami et al., 2000	29	Not indicated	T group: 34.7	No mention of hearing status	75	T: 2000, NT: 1000
Iwanami et al., 2001	10	Not indicated	T group: 36.6	No mention of hearing status	75	T: 2000, NT: 1000

Jahshan et al., 2012	109	18 - 60	T group (BPD): 45.2.5; T group (SZ): 45.6; C group: 39.5	No mention of hearing status	85	1000
Karaaslan et al., 2003	56	T group: 19 – 51 C group: 20 - 48	T group: 35.63; C group: 34.30	No mention of hearing status	Not indicated	T: 2000, NT: 1000
Katada et al., 2003	13	70 - 88	T group: 78.0	No mention of hearing status	70	T: 2000, NT: 1000
Kim et al., 2014	88	Not indicated	T group: 33.91: C group: 34.74	Evaluated hearing sensitivity - auditory functioning was examined using a 512-Hz tuning fork	85	T: 1500, NT: 1000
Kimble et al., 2000	30	28 - 70	T group (relatives): 44.1; C group: 43.7	No mention of hearing status	97	T: 1500, NT: 1000
Korostenskaja et al., 2005	26	T group: 18 - 55; C group: 23 - 55	T group: 31.9; C group: 34.7	No mention of hearing status	60	T: 1000, NT: 2000
Lebedeva & Orlova, 2001	60	T group (parents): 30 - 65; T group (siblings/children): 17 -35; C group 1: 30 -68; C group 2: 18 - 38	T group (parents): 51.8; T group (siblings/children): 24.9; C group 1: 49.3; C group 2: 26.0	Excluded participants based on self–reported hearing impairment	60	T: 1000, NT: 2000
Light et al., 2015	1790	Not indicated	T: group 46.25; C group: 38.63	Evaluated hearing sensitivity an unspecified hearing test was conducted to ensure a >40 dB hearing threshold bilaterally at 1000 Hz	85	1000
Mathalon et al., 2000	70	T group: 27 - 55; C group: 22 - 60	T group: 38.7; C group: 42.8	Excluded participants based on self–reported hearing impairment	80	T: 1000, NT: 500
Mathalon et al., 2002	20	T group: 22 - 54; C group: 32 - 67	T group: 40.5; C group: 50.1	No mention of hearing status	86	T: 1000, NT: 500
Mathalon et al., 2010	59	T group (SZ) : 22 - 56; T group (affective): 21 - 55; C group: 23 - 59	T group (SZ) : 39.95; T group (affective): 36.46; C group: 37.29	No mention of hearing status	80	T: 1000, NT: 500
O'Donnell et al., 2004	49	18 - 65	T group (BPD): 39.6; T group (SZ): 40.8; C group: 37.8	Excluded participants based on self–reported hearing impairment	86	T: 1500, NT: 1000
O'Donoghue et al., 2014	97	18 - 60	T group 1: 41; T group 2: 47.8; T group 3: 40.2; C group 1: 38.8; C group 2: 41.1; C group 3: 40.2	No mention of hearing status	80	T: 1500, NT: 1000
Ozgürdal et al., 2008	166	Not indicated	T group (prodromal): 26.11; T group (FE): 26.39; T group (chronic SZ): 37.96; C group: 27.78	No mention of hearing status	83	T: 1000, NT: 500
Perlman et al., 2015	136	16 - 60 (at first admission)	T group (SZ): 44.29; T group (psychosis): 43.98; C group: 45.80	No mention of hearing status	75	Not mentioned

Pokryszko-Dragan et al., 2003	26	56 - 77	T group: 68.6	No mention of hearing status	70	T: 2000, NT: 1000
Preskorn et al., 2014	21	18 - 55	T group (medication 1): 51.4; T group (medication 2): 43.1; T group (placebo): 40.0	No mention of hearing status	50 above threshold	T: 1000, NT: 500
Röschke et al., 2003	42	Not indicated	T group: 39; C group: 38.1	Excluded participants based on self–reported hearing impairment	80	T: 2000, NT: 1500
Schulze et al., 2008	117	18 - 60	T group: 43.3; T group (relatives): 43.2; C group: 40.2	No mention of hearing status	80	T: 1500, NT: 1000
Shin et al., 2010	59	Not indicated	T group: 36.8; T group (SPD): 39.2; C group: 36.4	No mention of hearing status	86	T: 1500, NT: 1000
Sumi et al., 2001	97	T group: 60 - 84; C group: 60 - 77	T group (SZ): 65.5; T group (AD): 69.6; C group: 68.5	Excluded based on a history of disorders known to be related to hearing loss	70	T: 1000, NT: 2000
Thomas et al., 2001	140	T group: 58 - 73; C group: 57 - 78	T group: 65.0; C group: 67.5	No mention of hearing status	75	T: 2000, NT: 500
Turetsky et al., 2015	1236	Not indicated	T group: 43	Evaluated hearing sensitivity an unspecified hearing test was conducted to ensure a >40 dB hearing threshold bilaterally at 1000 Hz	Not indicated	T: 1500, NT: 1000
Urretavizcaya et al., 2003	81	Not indicated	T group: 55.6; C group: 52.9	Excluded participants based on self–reported hearing impairment	75	T: 6000, NT: 2000
Van Der Stelt et al., 2005	62	T group (HR): 15 - 30; T group (RO SZ): 17 - 25; T group (chronic): 18 - 51; C group (younger): 19 - 25; C group (older): 24 - 57	T group (HR): 22.1; T group (RO SZ): 21.3; T group (chronic): 37.5; C group (younger): 22.5; C group (older): 34.1	Excluded participants based on self–reported hearing impairment	85	T: 1064, NT: 1000
Wang et al., 2010	44	T group: 16 – 57; C group: 17 – 52	T group: 28.63; C group: 32.88		80	T: 1500, NT: 1000
Winterer et al., 2001	138	18 - 60	T group: 37.0; T group (siblings): 36.9; C group: 35.2	No mention of hearing status	80	T: 1500, NT: 1000
Winterer et al., 2001	43	Not indicated	T group: 36.27; C group: 34,16	No mention of hearing status	65	T: 1000, NT: 2000
Winterer et al., 2003	270	18 - 60	T group: 36.8; T group (siblings): 37.0; C group: 34.9	No mention of hearing status	80	T: 1500, NT: 1000
Younger et al., 2005	254	Not indicated	T group: 38.1; C group: 38.0	No mention of hearing status	80	T: 1000, NT: 2000

AD: Alzheimer's disease; DLB: dementia with Lewy Bodies; MZ: monozygotic; DZ: dizygotic; SZ: schizophrenia; BPD: bipolar disorder; HR: high risk; RO: recent onset; FE: first episode; SPD: schizotypal personality disorder; T: test; C: control; T: target stimulus; NT: non-target stimulus

4. Discussion and conclusion

The auditory P300 response is widely investigated and applied clinically in selected neurological and psychological disorders. Usually, P300 response latency and amplitude are analyzed in participants that are suspected of, or diagnosed with, these disorders (Hall, 2015; Picton, 1992). Hearing loss influences both the amplitude and latency of the auditory P300 response (Picton, 1992; Reis et al., 2015). It is possible, indeed likely, that the inclusion of participants with peripheral hearing loss has affected the P300 results of some of these published studies and, therefore, the conclusions drawn from data analysis.

We found that authors of studies exploring the application of the auditory P300 response being clinically applied for neurological and psychological disorders do not consistently account for peripheral hearing sensitivity of participants. Over 90% of studies of the auditory P300 response did not include an evaluation or a description of participant hearing status and participants with hearing impairments were not excluded from these studies. The lack of documentation of hearing status was perhaps most troublesome for studies with participants over 50 years of age, and at greater risk of age-related hearing loss. These studies accounted for 42% of the articles reviewed. Decreased auditory P300 amplitudes and prolonged latencies are characteristic of persons with hearing loss (Pollock & Schneider, 1992; Reis et al., 2015). In addition, the degree and configuration of the hearing loss may differentially influence the P300 response for frequent (non-target) versus rare (target) stimuli. Furthermore, it is possible that participants with hearing loss may not completely hear or fully understand instructions for the required P300 task. Unrecognized or inadequately described hearing loss in participants in P300 studies may confound neurophysiological assessment of higher-level auditory function and cognitive function.

The relatively small proportion of studies that took hearing status into account relied on self-reports of hearing difficulty. There is a general agreement that self-reported hearing impairment and actual hearing status based on pure-tone hearing assessment are not well correlated (Choi et al., 2019; Nondahl et al., 1998; Valete-Rosalino & Rozenfeld, 2005). The inclusion or exclusion of participants in auditory P300 studies based on self-reported hearing status is not recommended. Rather,

participant hearing status is best defined with accepted methods and procedures for hearing assessment, such as pure tone audiometry conducted by a licensed audiologist or validated automated audiometer software (Hall, 2014).

Less than 10% of the reviewed studies included an evaluation of participant hearing sensitivity, and only two publications documented how hearing was assessed. Five studies did not indicate how hearing was assessed but stated that hearing thresholds were below 40 dB at 1000 Hz. None of the studies specified how hearing was assessed, or the skill level or training of personnel conducting the assessment.

Remarkably, the authors of only one study evaluated hearing sensitivity using a comprehensive diagnostic audiological test battery with the aim of excluding participants with any degree of hearing loss (Mattsson et al., 2019). The article was published in the *International Journal of Audiology*. Hearing assessment conducted in a sound isolated room, included pure tone audiometry, tympanometry, acoustic reflexes, otoscopic examination, word recognition score testing, and auditory brainstem response (ABR or BAER) measurements. Unfortunately, no information was provided on the clinical credentials of the person(s) who conducted the assessments. In this study (Mattsson et al., 2019), participants with hearing thresholds of greater than 20 dB were excluded. Clinical practice guidelines call for formal assessment of peripheral auditory status of children and adults who undergo diagnostic evaluation for APD with behavioural or electrophysiological procedures (American Academy of Audiology Practice Guidelines (Musiek et al., 2010)).

We are hopeful that this paper will increase awareness of the importance of adequately documenting peripheral hearing status and establish a greater appreciation of the effects of peripheral hearing sensitivity on the auditory P300 response among P300 researchers. We recommend regular documentation of peripheral hearing status of participants in all studies of the auditory P300, including those conducted by researchers from the disciplines of neurology, psychology, and psychiatry. Our review also suggests a role for hearing health care professionals in the peer-review process prior to the publication of manuscripts on the P300 being clinically applied for neurological and psychological disorders.

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