Psychological Medicine (2018), **48**, 879–888. © Cambridge University Press 2017
doi:10.1017/S0033291717002367

INVITED REVIEW

Auditory hallucinations across the lifespan: a systematic review and meta-analysis

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Background. Auditory Hallucinations (AH) are nowadays regarded as symptoms following a continuum; from a (transient) phenomenon in healthy individuals on one end to a symptom of (psychiatric) illnesses at the other. An accumulating number of epidemiological studies focused on the prevalence of AH in the general population, but results vary widely. The current meta-analysis aims to synthesize existing evidence on lifetime prevalence of AH across the lifespan.

Methods. We conducted a quantitative review and meta-analysis according to PRISMA guidelines. Studies were combined to calculate a mean lifetime general population AH prevalence rate. Moreover, prevalences were calculated for four age groups: children (5–12 years), adolescents (13–17 years), adults (18–60 years) and elderly (⩾60 years).

Results. We retrieved 25 study samples including 84 711 participants. Mean lifetime prevalence rate of AH was 9.6% (95% CI 6.7–13.6%). The mean lifetime prevalence was similar in children (12.7%) and adolescents (12.4%), but these two groups differed significantly from the adults (5.8%) and the elderly (4.5%). Significant heterogeneity indicated that there is still dispersion in true prevalence rates between studies, even within the different age categories.

Conclusions. Current meta-analysis shows that AH are quite common (up to one in ten individuals) in the general population during lifetime, with children and adolescents reporting these experiences significantly more often compared with adults and elderly. Large follow-up studies on the longitudinal course of AH are needed to reveal associated risk and resilience factors.

Received 30 November 2016; Revised 20 July 2017; Accepted 20 July 2017; First published online 28 September 2017

Key words: Adolescents, adults, auditory hallucinations, children, epidemiology, general population, prevalence.

Introduction

The psychotic experiences that characterize schizophrenia spectrum disorders have previously been described in terms of a psychosis continuum, ranging from benign and/or transient experiences in non-clinical individuals on one end, to psychotic symptoms in patients on the other end (Johns & van Os, 2001; Larøi, 2012). Therefore, the meaning of psychotic experiences goes beyond psychopathology. Research has indeed shown that well-functioning individuals with frequent psychotic experiences share a wide range of risk factors with clinical patients with psychosis, including developmental and environmental factors (Kelleher & Cannon, 2011; Daalman *et al.* 2012). In turn, presence of psychotic experiences is suggested to be an important risk marker for early psychopathology, as young people with hallucinatory and/or delusional experiences report higher rates of non-psychotic symptomatology, including symptoms of depression (Kelleher *et al.* 2012*b*), suicide attempts (Sommer *et al.* 2010*a*) and higher levels of thought disorder (Sommer *et al.* 2010*b*). Moreover, well-functioning individuals with frequent non-clinical psychotic experiences also show vulnerability factors including high rates of childhood trauma, reduced brain volume and lower cognitive performance (Sommer *et al.* 2010*a*; Kelleher & Cannon, 2011; van Lutterveld *et al.* 2014; Begemann *et al.* 2016) similar to, but to a lesser degree than patients with a psychotic disorder.

Van Os and colleagues conducted a meta-analysis in 2009 to investigate the prevalence of psychotic symptoms in the general population, comprising hallucinations and delusions. They reported a median prevalence of 5.3%, which was mainly based on studies in adults. An update by Linscott & van Os (2013) included additional studies on children and adolescents, showing a prevalence rate of 7.2%. Importantly, general psychotic experiences were

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found to be more common among younger individuals. Kelleher *et al.* (2012*a*) showed a higher median prevalence of 17% in children (9–12 years) compared with 7.5% in adolescents (13–18 years). A systematic review on the longitudinal course of general hallucinatory experiences during childhood and adolescence reported that discontinuation of hallucinatory experiences occurred in approximately 75% of the cases (person–year discontinuation 3% to 40.7% (Rubio *et al.* 2012). It has therefore been suggested that, while psychotic symptoms may be more commonly experienced during typical development as a child (van Os *et al.* 2009), these experiences become less frequent and increasingly indicative of pathology with advancing age (Kelleher *et al.* 2012*b*).

Next to the prevalence of general psychotic experiences, many epidemiological studies have specifically focused on the occurrence of auditory hallucinations (AH). The number of studies evaluating the frequency of AH of young and adult populations has been rapidly accumulating during the past years. However, prevalence rates are found to differ greatly between studies (Beavan *et al.* 2011; de Leede-Smith & Barkus, 2013; Jardri *et al.* 2014). For example, Beavan *et al.* (2011) found rates varying between 0.6% and 84%, resulting in a median prevalence of 13.2% of AH in the general adult population. The authors reported that comparisons between studies were problematic given the different methodologies used. Several factors may be responsible for this high variance, such as the period over which presence of AH is assessed (last week, last month, last year, or lifetime), the type of questionnaire used (e.g. self-rated *v.* interview-based, phrasing of questions), and age of the population studied. Following the high prevalence of psychotic experiences during childhood and adolescence, and the transient course of AH, it can be hypothesized that the prevalence of AH decreases after childhood.

To provide more insight in the occurrence of AH in the general population, aim of the current meta-analysis is to estimate the prevalence of AH across the lifespan by combining population-based samples, from childhood to old age. As age may be an important factor, the prevalence rates are also separately evaluated for different developmental groups: children, adolescents, adults and elderly.

Methods

Search strategy

This quantitative review was conducted following the guidelines described in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (www.prisma-statement.org/statement.htm; Moher *et al.* 2009). A systematic search for relevant studies published in English peer-reviewed journals was performed in Pubmed, EMBASE, PsychINFO. The search cut-off date was 31st January 2016. The following search terms were used: (prevalence OR prevalences OR prevalent OR epidemiology OR epidemiologic OR epidemiological) AND ('voice hearing' OR 'hearing voices' OR 'voice hearer' OR 'AVH' OR 'psychotic symptom' OR 'psychotic symptoms' OR 'psychotic experience' OR 'psychotic experiences' OR 'hallucination' OR 'psychotic like' OR 'psychosis like' OR 'hallucinatory' OR 'hallucinative' OR 'hallucinatic' OR 'hallucinoid'). In addition, review articles and eligible studies were examined for cross-references.

Eligibility criteria

To be eligible, the articles had to meet the following criteria:

(1) Data were provided on the lifetime prevalence of auditory (verbal) hallucinations, or suggested that this information was available
(2) The included cohort was a general population sample

Study selection and data collection

Two reviewers (L.C. and E.T.) independently examined titles and abstracts of all retrieved articles to select potential eligible articles. If consensus was not reached, a third reviewer (K.M.) was consulted. For every eligible article, the corresponding author was contacted by email to ask for original or complementary data, so we were able to recalculate prevalence rates for the different developmental age groups when necessary. In case multiple publications were retrieved that described the same cohort, only the sample with largest overall sample size and/or original data was included. When an article reported data on different cohorts, each cohort was regarded as a separate study sample.

Several decisions were made to optimise uniformity between studies:

(1) As the majority of studies provided self-report data, this was preferred over interviewer-rated data when both were reported in the article.
(2) When prevalence rates were separately reported for 'conscious' *v.* sleep and/or drug related AH, the first option was used.
(3) The answering options 'certainly'/'definite'/'yes' were considered as positive for experiences of AH, while 'possible'/'probable'/'maybe' were considered as negative; this, in line with previous

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prevalence studies. Similarly, 'sometimes' and 'often/always' were both considered as positive for AH and therefore prevalence rates were summed when an article reported both options separately.

In five study samples, the authors designed their own questionnaire to evaluate the experience of AH (Verdoux *et al.* 1998; Yoshizimi *et al.* 2004; Polanczyk *et al.* 2010; de Loore *et al.* 2011; Knobel & Lima, 2012). Four out of five screening questions were rather similar, specifically assessing AVH (Have you heard voices that other people cannot hear? Have you ever heard or are you currently hearing somebody's voice that no one around can hear? Have you ever heard voices other people cannot hear?), while the fifth evaluated AH in general (Do you have any noises in your ears or head?). These questionnaires were all grouped into one category termed 'designed by author'.

Data analysis

First, our aim was to calculate a weighed mean lifetime prevalence rate of AH in the general population. Therefore, we derived sample size and prevalence rate for each study sample. Second, we evaluated the specific prevalence rates within four different developmental age groups: children ($\leqslant$12 years), adolescents (13–17 years), adults (18–60 years) and elderly ($\geqslant$60 years) (Kelleher *et al.* 2012*b*). When the age range of an included cohort cut across the aforementioned developmental age ranges, original data were used to split the sample accordingly; sample size and prevalence rates were recalculated for each of the proposed age groups.

Studies were combined in meta-analysis to calculate a pooled estimate of general lifetime prevalence of AH in the general population. A random effects model was deemed most appropriate for this research area given the heterogeneity in applied methods (Borenstein *et al.* 2009). In random-effects meta-analysis, the observed effect size is expected to vary to some extend from study to study. To determine whether the observed variation falls within the range that can be attributed to sampling error or whether the variation reflects differences in true effect sizes, we assessed heterogeneity using the Q-statistic and the I^2-statistic (Borenstein *et al.* 2009) The Q-statistic tests the null hypothesis, stating that all studies in the analysis share a common effect size. If all studies shared the same effect size, the expected value of Q would be equal to the degrees of freedom (the number of studies minus 1). In addition, I^2 was calculated, which indicates the proportion of the observed variance reflecting differences in true effect sizes rather than sampling error. Moreover, it is important to investigate potential outlier studies, defined as standardized residual z-scores of effect sizes exceeding ± 1.96 ($p < 0.05$). All calculations were executed using Comprehensive Meta-Analysis version 2.0 (www.meta-analysis.com/) (Borenstein *et al.* 2005, 2009).

Results

In total 27 articles investigating the prevalence of AH in the general population were retrieved from the literature search. Six of these eligible publications described overlapping cohorts of which three articles with the smallest sample size were excluded (Lataster *et al.* 2006; Shevlin *et al.* 2011; Alsawy *et al.* 2015). One article investigated two different study populations (Wigman *et al.* 2011), which were entered as separate study samples. Therefore, 25 study samples were included with a total number of 84 711 participants. See the PRISMA flowchart (Fig. 1) for the study selection process.

Table 1 shows an overview of all 25 included study samples with calculated lifetime prevalence rates. We received original data from 19 of the 25 included study samples. The age range of four study samples without original data exactly fell within the proposed age groups, while two study samples (Mamah *et al.* 2012, 2013) did not. These two samples were designated to one age category based on the mean age of the study sample.

General prevalence of AH

Including the prevalence rates of all 25 study samples, the pooled estimate of prevalence was 9.6%, with the 95% confidence interval [95% CI 6.7–13.6% (n = 84 711)]. The Q and I^2 statistic both showed heterogeneity, $Q(24) = 6672.47$, $p < 0.001$, $I^2 = 99.64\%$, indicating that the true prevalence varies between studies. Indeed, the prevalence rates of the individual study samples ranged between 2% and 37.5%. No outliers were detected.

Developmental age categories: children, adolescents, adults and elderly

To evaluate whether prevalence rates differed between different age groups, the study samples were divided into four developmental age categories. This resulted in 36 study subsamples: nine subsamples evaluating AH in children 5–12 years; 13 adolescent subsamples of 13–17 years; nine subsamples evaluating adults aged 18–60 years and five subsamples on individuals aged $\geqslant$60 years.

Prevalence of AH was 12.7% in children (n = 14 878; 95% CI 8.1–19.3%; $Q(8) = 1142.91$, $p < 0.001$;

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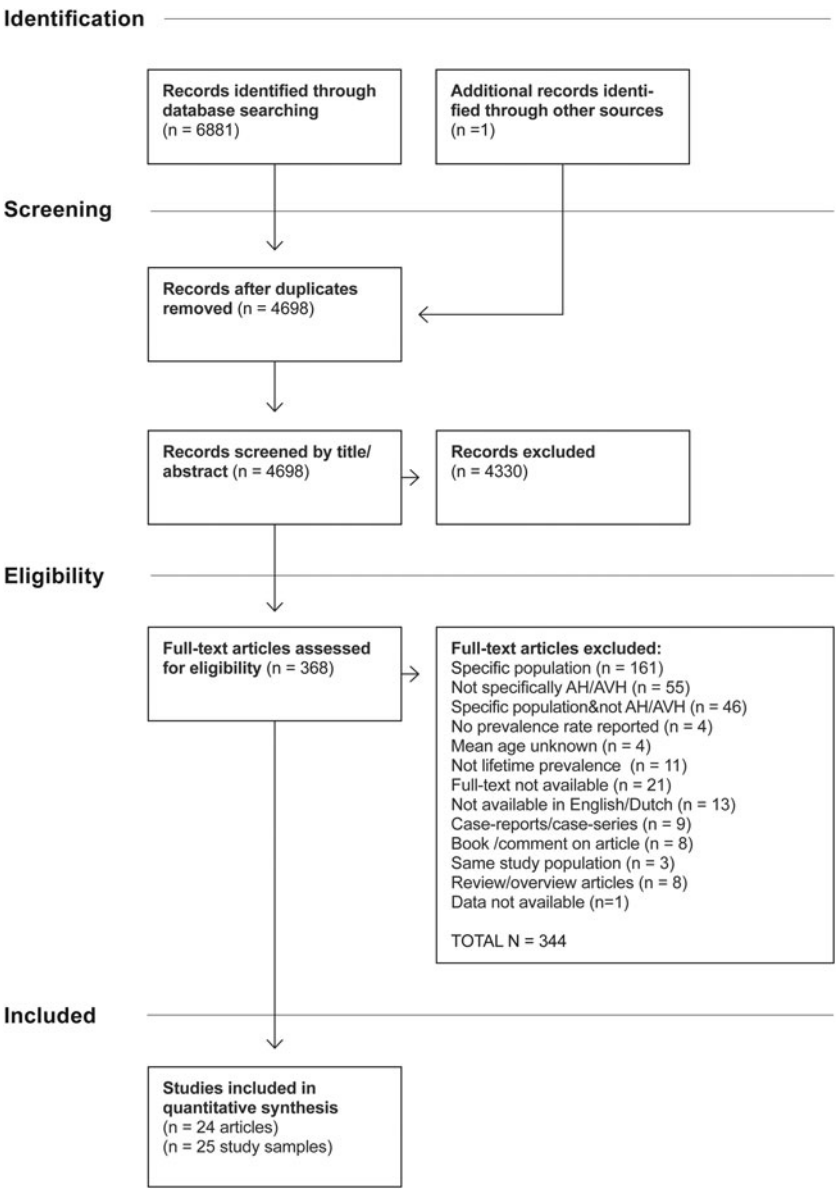

Fig. 1. PRISMA flow diagram of the performed literature search.

$I^2 = 99.30\%$), 12.4% for adolescents ($n = 33\,033$; 95% CI 8.3–18.1%; $Q(12) = 1333.40$, $p < 0.001$; $I^2 = 99.18\%$), 5.8% for adults ($n = 27\,375$; 95% CI 3.6–9.2%; $Q(8) = 289.91$, $p < 0.001$; $I^2 = 97.24\%$) and 4.5% for the elderly ($n = 9\,425$; 95% CI 2.5–8.1%; $Q(5) = 204.73$ $p < 0.001$; $I^2 = 97.56$) (see Fig. 2). The high Q- and I^2-values within each age subgroup analysis indicated that there was still evidence of dispersion in true prevalence rates among studies. The significant pooled Q-value [$Q(32) = 2970.94$; $p < 0.001$], evaluating whether this grouping (children *v.* adolescents *v.* adults *v.* elderly) could explain the variance in true effect sizes, also indicated that true variance remained even within the different developmental age subgroups.

When comparing the prevalence rates between the four age categories, prevalence was found to significantly vary with age [$Q(3) = 13.66$, $p = 0.003$]. *Post-hoc* analysis showed that the prevalence rate in both children (12.7%) and adolescents (12.4%) was significantly higher compared with the adult prevalence of 5.8% ($z = 2.39$; $p = 0.017$ and $z = 2.44$; $p = 0.015$, respectively). Children and adolescents also experienced more AH compared with the prevalence rate of 4.5% in the elderly ($z = 2.76$; $p = 0.006$ and $z = 2.81$; $p = 0.005$, respectively). The difference in prevalence in children *v.* adolescents was not significant ($z = 0.08$; $p = 0.094$), nor in adults *v.* elderly ($z = 0.66$; $p = 0.512$).

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Table 1. *Overview of the included studies and calculated lifetime prevalences*

Study sample	Prevalence (%)	Sample size	Continent	Mean age	Age range	Questionnaire	A(V)H
Eaton *et al.* (1991)[a]	5.3	3543	Europe	33.7	18–96	DIS(C)/– interview	AVH
Verdoux *et al.* (1998)[a]	19.3	457	Europe	56.8	18–93	Designed by author – self-report	AVH
Yoshizumi *et al.* (2004)	15.8	380	Japan	11.6	11–12	Designed by author – self-report	AVH
Kessler *et al.* (2005)[a]	8.3	2349	North America	44.3	18–95	CIDI 3.0- interview	A(V)H
Shevlin *et al.* (2007)[a]	4.8	5907	North America	32.0	15–59	CIDI – interview	A(V)H
Pearson *et al.* (2008)	33.4	500	Europe	14.8	14–15	HQ – self-report	AVH
Scott *et al.* (2008)[a]	3.5	2534	Australia	19.9	18–23	CIDI – interview	A(V)H
Yung *et al.* (2009)	29.8	875	Australia	15.6	13–18	CAPE – self-report	AVH
Polanczyk *et al.* (2010)	4.2	2127	Europe	12.0	12	Designed by author – self-report	AVH
Barragan *et al.* (2011)	37.5	777	Europe	14.4	13–17	CAPE – self-report	AVH
De Loore *et al.* (2011)	5.3	2100	Europe	14.3	13–16	Designed by author – self-report	AVH
Nakazawa *et al.* (2011)	10.3	4864	Japan	13.8	12–15	DIS(C) – self-report	AVH
Wigman *et al.* (2011)-I	9.0	1643	Europe	10.8	10–12	CAPE – self-report	AVH
Wigman *et al.* (2011)-II[a]	22.2	4550	North America	13.9	12–16	CAPE – self-report	AVH
Knobel & Lima (2012)[a]	2.0	733	South America	9.8	5–16	Designed by author – interview	AH
Laurens *et al.* (2012)	35.1	7780	Europe	9.9	9–11	DIS(C) – self-report	AVH
Mamah *et al.* (2012)	6.9	2627	Africa	18.5	14–29	mPRIME – self-report	A(V)H
Mamah *et al.* (2013)	12.7	1199	Africa	13.0	8–19	CIDI – self-report	A(V)H
Cederlöf *et al.* (2014)	4.3	5343	Europe	15.9	15–18	DIS(C) – interview	AVH
Soares *et al.* (2015)	7.5	1124	South America	70.8	⩾60	CAMDEX- interview	AH
Adriaanse *et al.* (2015)[a]	10.3	702	Europe	13.2	8–17	K-SADS – self-report	AVH
Dolphin *et al.* (2015)[a]	13.7	5867	Europe	15.0	12–19	APSS – self-report	AH
Kompus *et al.* (2015)[a]	10.6	9646	Europe	16.9	16–19	LSHS – self-report	AVH
Kråkvik *et al.* (2015)[a]	6.8	2533	Europe	49.6	19–96	LSHS – self-report	AVH
Sharifi *et al.* (2015)[a]	2.1	14 551	North America	49.5	18–92	DIS(C) – interview	AVH

[a] Studies for which prevalence rates were recalculated based on original data.

A(V)H, Auditory (verbal) hallucinations; DIS(C), Diagnostic Interview Schedule (Child); CAPE, Community Assessment of Psychic Experiences; CIDI, Composite International Diagnostic Interview; K-SADS, Kiddie-Schedule for Affective Disorders and Schizophrenia; HQ, Hallucination Questionnaire; LSHS, Launay-Slade Hallucinations Scale; APSS, Adolescent Psychotic-Like Symptom Screener; CAMDEX, Cambridge Mental Disorders of the Elderly Examination.

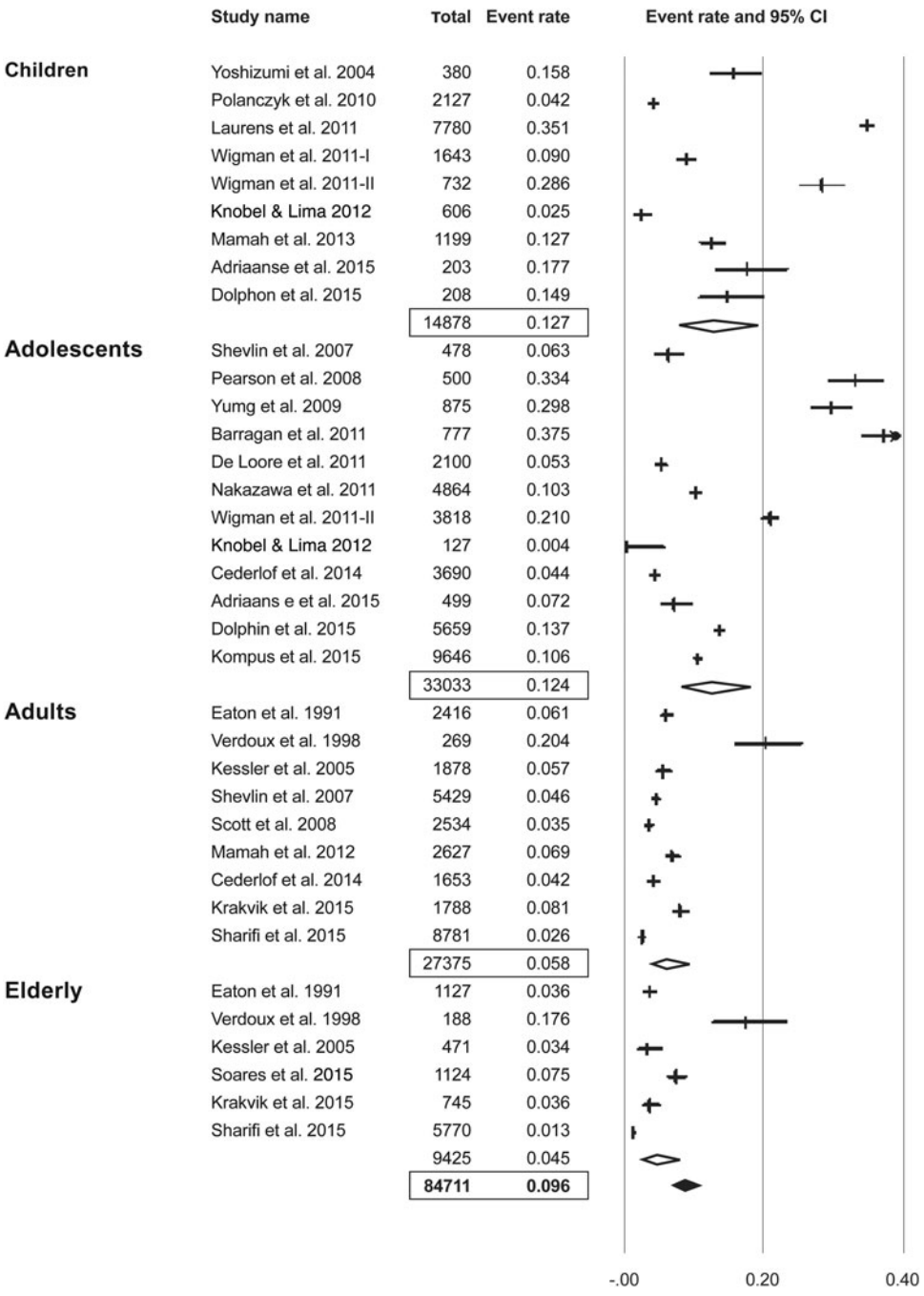

Fig. 2. Prevalence of A(V)H in the different developmental age groups.

Discussion

Current meta-analysis included 25 study samples evaluating the prevalence of AH in the general population across the lifespan, with a total of 84 711 participants. We found a mean prevalence rate of 9.6% (95% CI 6.7–13.6%). When evaluating different age groups, the mean lifetime prevalence of AH was similar in children (12.7%) and adolescents (12.4%), but these two groups differed significantly from adults (5.8%) and elderly (4.5%).

Decreasing trend in lifetime prevalence

Our results suggest that AH are quite prevalent in children and adolescents, with more than 1 in every 10 individuals reporting these experiences. After adolescence, this prevalence rate decreases by half. When assessing lifetime prevalence numbers however, one would expect a general increasing trend with older age as a result of cumulative experiences over the years. Our data did not reflect such a trend. It could

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well be the case that lifetime prevalence estimates are biased downwards due to underreporting (McGrath *et al.* 2015), implicating the role of memory or recall bias. We speculate that AH at a younger age tend to be forgotten later in life, when infrequent and/or non-distressing. Indeed, AH are sporadic and simple in most cases as McGrath *et al.* (2015) showed that 64% of the participants with psychotic experiences only had these once to five times in their lives. Regarding distress, while only 15% of young children report suffering (i.e. fear, distress and/or dysfunction) from AH (Bartels-Velthuis *et al.* 2010), this percentage increases with age, up to 70% in the elderly (Tien, 1991).

It could also be that the common (and mostly transient) character of AH in childhood reflects typical development (van Os *et al.* 2009). The course of brain maturation starts during fetal development and continues into young adulthood (Toga *et al.* 2006). Gray and white matter studies show that the language areas mature around puberty (11–13 years; Gogtay *et al.* 2004). We hypothesize that immaturity of these areas might lead to a (transient) vulnerability for spontaneous, aberrant activity resulting in AH. The more advanced 'executive' functions, e.g. inhibition and source- and self-monitoring, mature later during late adolescence (Gogtay *et al.* 2004), and thereby the increasing ability to accurately interpret stimuli and phenomena such as inner speech during adolescence. Accordingly, patients with a psychotic disorder but also healthy individuals with AH show reduced executive functioning (Aas *et al.* 2014; Begemann *et al.* 2016). While the common transient and 'benign' AH experiences in childhood (due to aberrant auditory stimuli or limited executive abilities) may decrease with age, the incidence of psychopathology-related AH is known to increase in adolescence (Kelleher *et al.* 2012*b*; Schimmelmann *et al.* 2015), which could explain the relatively higher prevalence rates we found in both children and adolescents.

Methodological considerations

The Q- and I^2-values showed high heterogeneity within the mean lifetime prevalence estimate. While age was expected to be an explanatory factor, heterogeneity remained high within the different developmental age groups. This indicates that factors other than age are involved. One explanation could be the different questionnaires used in the separate studies. The 25 study samples used 11 different rating scales. When categorized by each of the different questionnaires, the mean prevalence ranged from 3.9% to 33.4%. Retrospectively, we quantitatively compared prevalence rates between scales but found that these differences did not reach significance [$Q(10) = 8.850$, $p = 0.546$], suggesting that type of questionnaire is not an explanatory factor *per se*. When qualitatively evaluating the different questions used to screen for AH, almost half of the studies used identical phrasing even though different questionnaires were used [namely the DIS(C), KSADS, APSS and four out of the five 'designed by author' questionnaires]. Moreover, the variety in definitions of AH does not seem to result in a specifically high or low prevalence. For example, a broad definition like 'Do you have any noises in your ears or head' as applied by Knobel & Lima (2012) yielded one of the lowest prevalence rates (2.0%), while Pearson *et al.* (2008) asked for specific forms of AH and found one of the highest prevalence rates (33.4%). Importantly, even when studies did use the same questionnaire, prevalence estimates also showed large variety. For example, three studies used the DIS(C) in a young population – while Cederlöf *et al.* (2014) found an interview-rated prevalence of 4.3%, self-reported prevalences were 10.3% and even 35.1% (Nakazawa *et al.* 2011; Laurens *et al.* 2012). This can partly be due to the observation that although the DIS(C) and CIDI are designed as interviews, these were also applied as self-report questionnaires in some studies. Response rates could therefore be 'confounded' by the incapacity of distinguishing 'true' AH from other aberrant auditory perceptions, especially when using self-report questionnaires instead of interviews. However, self-report does not necessarily lead to higher estimates. A questionnaire such as the CAPE, which is solely used as self-report, revealed both relatively low estimates (9.0% for Wigman *et al.* 2011-I) as well as relatively high estimates (22.2% for Wigman *et al.* 2011-II, 29.8% for Yung *et al.* 2009 and 37.5% for Barragan *et al.* 2011). This would suggest that neither type of questionnaire nor type of assessment (self-report *v.* interview) explains the heterogeneity. Other factors than type of questionnaire or type of assessment, for example the setting of testing and the introduction of the test, are more likely to be of influence (Beavan *et al.* 2011). A systematic evaluation of these methodological factors was not possible in current meta-analysis, given the large variety of applied methods compared to the relatively low number of studies in each developmental age group.

Future directions and implications for research

Our findings underline previous statements about the relatively common character of AH in the general population and can help in de-stigmatizing and normalizing these experiences in both young, adult and elderly populations (Beavan *et al.* 2011). Although there is abundant information on the prevalence of AH, only few studies provide longitudinal data, which is of great clinical relevance to AH experiences.

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Knowledge on which individuals with AH (eventually) warrant clinical care is needed to further develop prevention and early intervention strategies. Future studies should therefore include large follow-up datasets to allow a more detailed view on the course of AH with age and possible associated developmental risk and resilience factors.

Conclusion

The current meta-analysis shows that AH are quite common in the general population, with one in ten individuals reporting these experiences (mean prevalence 9.6%). Children (12.7%) and adolescents (12.4%) report significantly more AH compared with adults (5.8%) as well as elderly (4.5%). In order to support the development of prevention and intervention strategies, future large follow-up studies are needed to provide more details on the longitudinal course of AH and reveal concurrent risk and resilience factors.

Acknowledgements

We thank Ms. Laura Claus and Ms. Lisa Tijong for their efforts in performing the search and screening for eligible articles. Furthermore, we kindly thank all authors (and the support of NIDA grant DA026652 for the study of Sharifi and colleagues, 2015) who provided us with their original data or guided us to the freely available databases that they had used.

Declaration of Interest

None.

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