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An epidemiological study on the prevalence of hallucinations in a general-population sample: Effects of age and sensory modality

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ABSTRACT

Epidemiological studies have repeatedly shown that a significant minority of the general population have experienced hallucinations, however, a potential effect of age on the prevalence of hallucinations in the general population has never been previously examined in a specific study. The aim of the present study was thus to examine the effects of age and sensory modality on hallucination prevalence in a general population sample. A large, randomly selected and representative sample of the Norwegian population completed measures assessing different hallucination modalities (auditory, visual, olfactory, and tactile) and types (sensed presence and hypnagogic/hypnopompic hallucinations). Three age groups were identified and compared: young (19–30 years), middle (31–60) and old (61–96). There was a significant main-effect of age for all hallucination modalities and types, whereby hallucination prevalence significantly decreased with age. We also found that anxiety partially mediated the effect of age on hallucinations whilst depression was a partial suppressor. Concerning the co-occurrence of hallucination modalities, there was very little co-occurrence of auditory and visual hallucinations in all three age groups. In summary, a main-effect of age for hallucination prevalence was observed. Furthermore, individuals reported a more diverse variety of hallucination modalities compared to what is commonly reported in clinical populations.

1. Introduction

Hallucinations may be defined as sensory experiences that take place in the absence of a corresponding external stimulation, and may involve several modalities (e.g. auditory, visual, olfactory, tactile). Although common in psychotic disorders, hallucinations may also be experienced in other clinical conditions such as major depression, bipolar disorder and borderline personality disorder (Aleman and Larøi, 2008). Moreover, epidemiological studies have reported that a significant minority in the general population may experience hallucinations (for a review see Johns et al., 2014). In a recent meta-analysis, Maijer et al. (2018) found a 9.6% lifetime prevalence rate of auditory hallucinations in the general population, and this was similar to what Beavan et al. (2011) reported (median prevalence rate of 13.2% for auditory hallucinations) in their narrative review. Prevalence rates for all hallucination types and modalities grouped together have also been calculated: Linscott and van Os (2010) reported a median lifetime hallucination prevalence rate of 4.1% and a cross-national (52 countries) study (Nuevo et al., 2012) reported an age- and gender-adjusted estimate of 5.8%.

However, epidemiological studies have not examined a potential age-effect of hallucinations in the general population, but rather, have estimated prevalence rates within specific age groups. The majority of studies have calculated this within adult populations (often approximately 18–30 years old), or specifically in children/adolescent samples or exclusively in elderly samples (e.g. 60 years or older). Age may, however, be an important factor in itself to take into account when trying to understand the nature of hallucinations in the general

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population, and in particular whether age affects hallucinations differently across sensory modalities and hallucination types.

Maijer et al. (2018) conducted a meta-analysis of epidemiological studies that had examined the prevalence of auditory hallucinations rates for four age groups: children (5–12 years), adolescents (13–17 years), adults (18–60 years) and elderly (≥ 60 years). Twenty-five study samples were retrieved (84,711 participants). The mean lifetime prevalence rates were 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%). Results showed that auditory hallucinations are quite common (10%) in the general population during lifetime, with children and adolescents reporting these experiences significantly more often compared with adults and the elderly. However, significant heterogeneity indicated that there was dispersion in true prevalence rates between studies, even within the different age categories. The authors mention that one explanation of this heterogeneity could be the fact that the studies included in the meta-analysis used different measures in the separate studies. The authors also argue that this heterogeneity may indicate that factors other than age are involved. Also, the adult category included in the meta-analysis (ranging from 18 to 60 years of age) is very broad, which includes several age categories (including the high risk years, usually around 18–25 years of age). This may be why, for example, there were no differences between the adult and elderly groups. Thus, in order to examine age-effects in a more direct and suitable manner, it would be necessary to include all age groups within the same study. Further, it is important to include relatively specific age-groups, thus avoiding broad age-groups.

To the best of our knowledge, only one study (Larøi et al., 2005) has compared different age groups from the general population in terms of hallucination-proneness. Larøi et al. (2005) compared a sample of young (18–30 years old) and elderly adults (60–75 years old) from the general population and found that the two groups differed in terms of relations between their degree of hallucination-proneness (measured with a modified version of the Launay-Slade Hallucinations Scale, LSHS; Larøi and Van der Linden, 2005) and personality domains (measured with the NEO Personality Inventory; Costa and McCrae, 1992). For the young sample, there were significant associations between LSHS-scores and both the Openness to Experience and the Neuroticism domains, whereas for the elderly participants, only the Openness to Experience domain was significantly associated with LSHS-scores. This suggests that higher levels of neuroticism – or sensitivity to negative affect such as anxiety and depression – potentially plays a role in hallucination-proneness in younger samples from the general population, but does not seem to do so in older samples.

It is important to look at age as it may be a factor that helps explain the nature of hallucinations in the general population, yet this issue has been largely ignored. Also, it is important to examine this issue in the same study so that methodological aspects are kept constant, such as participants coming from the same general population, the same measures being used across age groups, etc. Indeed, in their meta-analysis, Maijer et al. (2018) observed significant heterogeneity in prevalence rates between studies, even within the different age categories. Further, previous studies have not compared hallucination modalities and types in a general population sample, yet this is an issue that has important theoretical implications (McCarthy-Jones et al., 2017).

The aim of the present study was to examine the effect of age on hallucination prevalence in a large, randomly selected and representative general population sample. In addition, we examined the effect of age on different hallucination modalities (auditory, visual, olfactory, tactile) and different types of hallucinations (sensed presence, hypnagogic/hypnopompic hallucinations). Finally, negative affect (anxiety and depression) was also examined since this factor has previously been shown to differentiate younger and older samples from the general population in terms of hallucination-proneness.

2. Methods

2.1. Participants

A randomly selected and representative sample of the Norwegian population aged 18 years or older was invited to participate (via a postal questionnaire) in a cross-sectional study of the prevalence of auditory hallucinations in the Norwegian general population (for more details see Kråkvik et al., 2015). Both participants who have experienced hallucinations and those who have not, were invited to participate. In order to avoid cultural differences in the sample, participants had to fulfil the following criteria: (a) born, raised, and currently living in Norway and (b) able to speak and understand Norwegian.

The randomization was conducted by the Norwegian Central Bureau of Statistics. In total, 8000 individuals aged 18 and older were invited to participate via postal questionnaires. The first 1000 individuals who completed the questionnaire received a lottery ticket as an incentive for participating in the study. A reminder was sent to all the 8000 individuals six weeks after the initial invitation. A total of 169 individuals could not be reached and 11 individuals refused to participate in the study, leaving 7820 individuals who were contacted and did not explicitly decline to participate. Of the 7820 individuals, 2533 (32.4%) completed and returned the questionnaire and a further 72 were excluded due to missing data, and therefore 2461 constituted the final study sample. Three age groups were created: young (19–30 years of age), middle age (31–60) and old (61 and higher). The study was approved by the Regional Committee for Medical Research Ethics in Central Norway (REK Central) and all participants gave their informed consent prior to their inclusion in the study. Descriptive statistics for the three age groups are presented in Table 1. For ANOVAs, alpha was set at 0.05 and adjusted using a familywise error rate method combining Bonferroni and Rüger tests (Hommel, 1983; 1988).

2.2. Questionnaire

Assessment of hallucinations was based on a Norwegian translation of the LSHS (Launay and Slade, 1981), which is a self-report

Table 1
Demographics.

	Young (19–30 years)		Middle age (31–60 years)		Old (61–96 years)	
	Mean (SE)	*N* (%)	Mean (SE)	*N* (%)	Mean (SE)	*N* (%)
Age	24.55 (0.19)	349	46.11 (0.22)[a]	1462	69.67 (0.29)[a,b]	650
Sex (M/F)		129/220 (36.9/63.1%)		653/809 (44.7/55.3%)		346/304 (53.2/46.8%)
Level of education (years)						
Elementary and lower secondary school		18 (5.2%)		122 (8.3%)		246 (37.9%)
Vocational school		78 (22.3%)		375 (25.6%)		133 (20.5%)
High school		96 (27.5%)		181 (12.4%)		45 (6.9%)
Bachelor's degree		94 (26.9%)		343 (23.5%)		121 (18.6%)
Master's degree and over		61 (17.5%)		439 (30.0%)		100 (15.4%)

[a,b] $p < .0001$.

Table 2
Analyses of variance (ANOVAs) comparing hallucinations for all 6 modalities and types in the three age groups and post-hoc Tukey's HSD tests.

	Young N = 349 mean (SE)	Middle age N = 1462 mean (SE)	Old N = 650 mean (SE)	F (2, 2458)	p	ηp^2
Auditory	0.43 (0.04)	0.19 (0.01)[a]	0.11 (0.02)[a, b]	35.49	< 0.0001	0.028
Olfactory	0.92 (0.07)	0.56 (0.03)[a]	0.36 (0.03)[a, b]	30.25	< 0.0001	0.024
Tactile	0.82 (0.07)	0.40 (0.02)[a]	0.25 (0.03)[a,b]	37.16	< 0.0001	0.029
Visual	0.70 (0.06)	0.42 (0.02)[a]	0.25 (0.03)[a,b]	28.92	< 0.0001	0.023
Sensed presence	0.87 (0.07)	0.74 (0.03)	0.59 (0.04) [a]	6.05	< 0.01	0.004
Hypnagogic /Hypnopompic	0.87 (0.06)	0.51 (0.02)[a]	0.35 (0.03)[a,b]	37.01	< 0.0001	0.029

A significant main effect of age remained after controlling for gender (ANCOVA). In particular, all the p values were $p < .0001$ except for sensed presence that reached $p = .02$. However, post-hoc analyses showed that the original difference observed for sensed presence between the young and the old age group remained significant ($p = .001$).

[a] Statistically significant compared to Young ($p < .013$, adjusted alpha).
[b] Statistically significant compared to Middle ($p < .013$, adjusted alpha).

Table 3
Analyses of variance (ANOVAs) comparing emotional factors in the three age groups and post-hoc Tukey's HSD tests.

	Young	Middle age	Old	F (2, 2391)	p	ηp^2
	N = 344	N = 1432	N = 618			
	Mean (SE)	Mean (SE)	Mean (SE)			
Anxiety	12.84 (0.18)	11.59 (0.09)[a]	10.81 (0.13)[a, b]	40.29	< 0.0001	0.032
Depression	9.79 (0.16)	9.84 (0.08)	10.74 (0.12)[a, b]	21.91	< 0.0001	0.017

[a] Statistically significant compared to Young ($p < .013$, adjusted alpha).
[b] Statistically significant compared to Middle ($p < .013$, adjusted alpha).

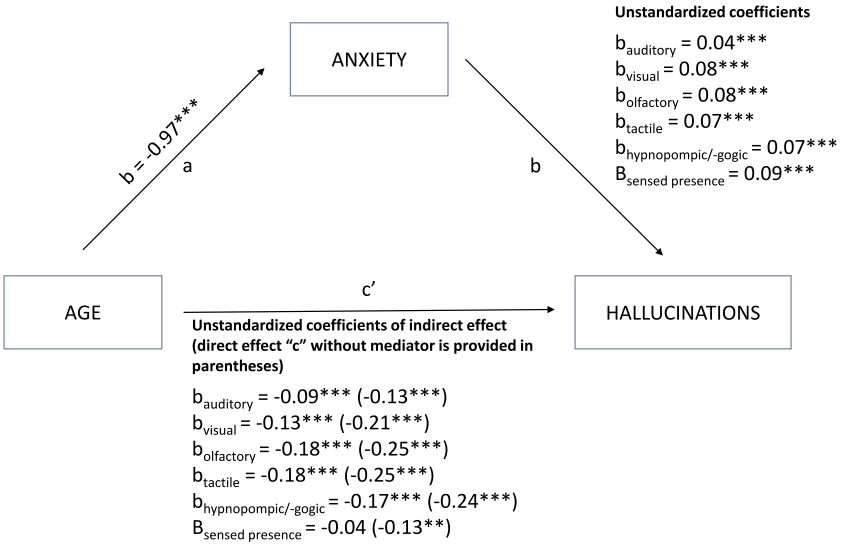

Fig. 1. Indirect effect of age on hallucinations mediated by anxiety.

questionnaire designed to assess hallucination proneness. The version of the LSHS used was based on Larøi and Van der Linden (2005) and Larøi et al., (2004). It was translated from English to Norwegian using the back-translation procedure. Compared with the original version (Launay and Slade, 1981), the version used in our study included additional items that identify hallucinatory experiences in other modalities (visual, tactile, olfactory), one item that assesses the feeling of presence ("On certain occasions I have felt the presence of someone close who has passed away") and, finally, one item that covers hypnagogic and hypnopompic hallucinations ("Sometimes, immediately prior to falling asleep or upon awakening, I have had the experience of having seen, felt or heard something or someone that wasn't there, or I have had the feeling of being touched even though no one was there"). For all items, participants were required to answer according to a five-point response scale: 0 = "certainly does not apply to me", 1 = "possibly does not apply to me", 2 = "unsure", 3 = "possibly applies to me" and 4 = "certainly applies to me" .

All participants were also asked to complete the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983), which is a fourteen-item questionnaire that measures the severity of anxiety (7 items) and depression (7 items). Each item is rated on a four-point response scale, generating a total score ranging from 0 to 21. Both the anxiety (Cronbach's alpha = 0.82) and depression (Cronbach's alpha = 0.80) subscales showed good internal consistency.

3. Results

Descriptive statistics for the three age groups are presented in Table 1. A one-way ANOVA revealed a significant effect of age [$F(2, 2458) = 4371.17$; $p < .0001$; $\eta p^2 = 0.780$]. Post-hoc analyses (Tukey' HSD) revealed that all three groups were significantly different from each other in terms of age (see Table 1).

Concerning hallucinations in the various modalities and types of hallucinations (auditory, olfactory, tactile, visual, sensed presence,

Table 4
Mediation analysis for anxiety. Coefficients, model estimate parameters, indirect effects, and effect sizes (expressed as completely standardized effect coefficients).

Type of hallucination/ modality	c path	b path	c' path	Indirect unstandardized bootstrapped effect	Completely standardized effect
	direct effect of age on hallucination without mediator	indirect effect with anxiety as mediator	indirect effect with anxiety as mediator	difference between direct and indirect effect	effect size measure for mediation
Auditory	$b = -0.13$, $t(2392) = 7.17$***	$b = 0.04$, $t(2932) = 12.83$***	$b = -0.09$, $t(2932) = 5.02$***	$b = -0.04$, Lower CI = −0.06, Upper CI = −0.03	$b^* = -0.05$, Lower CI = −0.06, Upper CI = −0.03
	Model: $F(1,2392) = 51.48$***, $R^2 = 0.02$	Model: $F(2,2391) = 109.82$***, $R^2 = 0.08$			
Visual	$b = -0.21$, $t(2392) = 7.16$***	$b = 0.08$, $t(2932) = 14.98$***	$b = -0.13$, $t(2932) = 4.71$***	$b = -0.08$, Lower CI = −0.01, Upper CI = −0.05	$b^* = -0.05$, Lower CI = −0.07, Upper CI = −0.04
	Model: $F(1,2392) = 51.21$***, $R^2 = 0.02$	Model: $F(2,2391) = 140.23$,***, $R^2 = 0.11$			
Olfactory	$b = -0.25$, $t(2392) = 7.04$***	$b = 0.08$, $t(2932) = 12.37$***	$b = -0.18$, $t(2932) = 4.95$***	$b = -0.08$, Lower CI = −0.10, Upper CI = −0.06	$b^* = -0.04$, Lower CI = −0.06, Upper CI = −0.03
	Model: $F(1,2392) = 49.59$***, $R^2 = 0.02$	Model: $F(2,2391) = 102.89$***, $R^2 = 0.08$			
Tactile	$b = -0.25$, $t(2392) = 7.73$***	$b = 0.07$, $t(2932) = 12.66$***	$b = -0.18$, $t(2932) = 5.61$***	$b = -0.07$, Lower CI = −0.10, Upper CI = −0.05	$b^* = -0.05$, Lower CI = −0.06, Upper CI = −0.03
	Model: $F(1,2392) = 59.69$***, $R^2 = 0.02$	Model: $F(2,2391) = 111.94$***, $R^2 = 0.09$			
Hypnagogic/ hypnopompic	$b = -0.24$, $t(2392) = 7.98$***	$b = 0.07$, $t(2932) = 13.97$***	$b = -0.17$, $t(2932) = 5.69$***	$b = -0.07$, Lower CI = −0.09, Upper CI = −0.05	$b^* = -0.05$, Lower CI = −0.06, Upper CI = −0.04
	Model: $F(1,2392) = 63.73$***, $R^2 = 0.03$	Model: $F(2,2391) = 132.04$***, $R^2 = 0.10$			
Sensed presence	$b = -0.13$, $t(2392) = 3.07$**Model:	$b = 0.09$, $t(2932) = 12.73$***	$b = -0.04$, $t(2932) = 0.86$, $p = .390$	$b = -0.09$, Lower CI = −0.12, Upper CI = −0.07	$b^* = -0.05$, Lower CI = −0.06, Upper CI = −0.03
	$F(1,2392) = 9.41$**, $R^2 < 0.01$	Model: $F(2,2391) = 86.01$, $R^2 = 0.07$			

Notes: CI = confidence interval (95%); * $p < .05$; ** $p < .01$; *** $p < .001$.

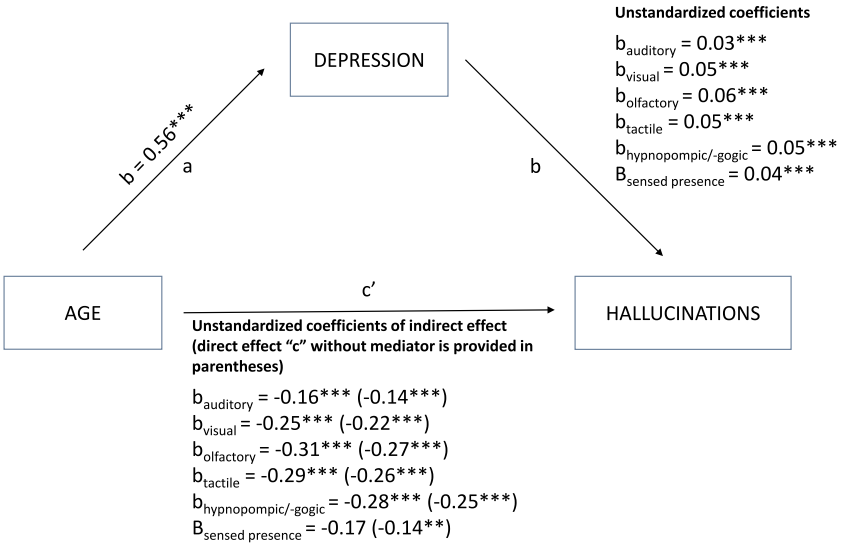

Fig. 2. Indirect effect of age on hallucinations mediated by depression.

hypnagogic/hypnopompic), one-way ANOVAs revealed a significant main effect of age for all modalities (see Table 2). Follow-up post-hoc analyses (Tukey' HSD) within each modality and type, and between age-groups were conducted. All age-groups differed significantly from each other for auditory, olfactory, tactile, visual and hypnagogic/hypnopompic hallucinations. The differences decreased with age (young > middle > old). Concerning sensed presence, although there was a decrease in prevalence rates across age groups, results only showed a statistically significant difference between the young and the old age group (young > old).

Results from the one-way ANOVAs between age groups and anxiety/depression subscale scores revealed a significant main effect of age group. Follow-up post-hoc analyses (Tukey' HSD) revealed that all age groups differed significantly from each other, except the comparison between the young and middle age group for the depression subscale score (see Table 3).

3.1. Mediation analyses

In order to further examine whether the reduced reports of hallucinations in older-aged adults is mediated by emotional factors, mediation analyses were carried out. We carried out two separate mediation analyses, one with the anxiety subscale and one with the depression subscale of the HADS as a mediator. In both analyses, age was the predictor, coded in three groups: young = 1, middle age = 2, and old = 3. The dependent variable were the six different hallucination types/modalities, thus six simple mediation models were computed. The mediation analysis for anxiety, along with the main coefficients, is presented in Fig. 1. All other coefficients, model estimation parameters, indirect effects, and effect sizes are provided in Table 4. Accordingly, the mediation analysis for depression is shown in Fig. 2 and Table 5.

3.2. Mediation analysis: degree of anxiety

Age was negatively associated with anxiety (b = -0.97, t(2392) = 8.82, $p < .001$, F(1, 2392) = 77.78, $p < .001$, $R^2 = 0.032$; see path a in Fig. 1), indicating that as age groups got older anxiety was reduced. Second, anxiety was positively related to all six hallucination measures (all bs ≥ 0.04, all ts(2392) ≥ 3.07, all ps < 0.002, see path b in Fig. 1), indicating that higher anxiety scores were associated with more frequently reported hallucinations. Finally, there was a negative association between age and hallucination, significant for each hallucination measure (all bs ≤ -0.13, all ts(2392) ≥ 12.37, all ps < 0.001, see values in parentheses of c' path in Fig. 1). That is, as age groups got older, fewer hallucinations were reported. When anxiety was included as a mediator, these negative associations were consistently weaker (see values in c' path in Fig. 1). The association between age and "sensed presence" was no longer significant ($b = -0.035$, t(2932) = 0.86, $p = .390$). However, for all other hallucinations there was still a significantly negative association (all bs ≤ -0.03, all ts(2392) ≥ 4.71, all ps < 0.0001) suggesting a partial mediation effect.

To test whether these indirect associations were significantly different from the direct model without anxiety as a mediator, 95% confidence intervals of the indirect effect were calculated based on bootstrapping (number of samples 5000) with the SPSS script PROCESS (Hayes, 2018). For each hallucination type/modality, the indirect effect was negative (all bs ≤ -0.04) and the lower and upper 95% confidence bands did not include zero, implying that the age-hallucination association became significantly weaker after including anxiety as a mediator. The effect sizes, expressed in completely standardized coefficients (Hayes, 2018), however, were relatively low (see Table 4). The mediation model with anxiety and age as predictors accounted for 7–11% of the variance in all hallucination measures, while age alone accounted only for roughly 2–3% in most cases (see Table 4).

3.3. Mediation analysis: degree of depression

Age was positively associated with depression (b = 0.56, t(2422) = 5.70, $p < .001$, F(1, 2422) = 32.51, $p < .001$, $R^2 = 0.013$; see path a in Fig. 2), indicating that as age groups got older depression was increased. Second, depression was positively related to all six hallucination measures (all bs ≥ 0.03, all ts(2422) ≥ 5.27, all ps < 0.001, see path b in Fig. 2), indicating that higher depression scores were associated with more frequently reported hallucinations. Finally, here too, was a negative association between age and hallucination, significant for each hallucination measure (all bs ≤ -0.14, all ts(2422) ≥ 3.49, all ps < 0.001, see values in parentheses of c' path in Fig. 2), with older age groups reporting fewer hallucinations. When depression was included as a mediator, these negative associations were consistently even more negative (see values in c' path in Fig. 2, all bs ≤ -0.16, all ts(2422) ≥ 4.09, all ps < 0.001). This suggests a partial suppression effect: Because depression increases with age and depression increases the likelihood of reporting hallucinations, depression suppresses the age normally negative association between age and hallucinations. The bootstrapping confirmed that the indirect effect was always positive (all bs = 0.02–0.03) and significant for all hallucination

Table 5
Mediation analysis for depression. Coefficients, model estimate parameters, indirect effects, and effect sizes (expressed as completely standardized effect coefficients).

Type of hallucination/ modality	c path	b path	c' path	Indirect unstandardized bootstrapped effect	Completely standardized effect
	direct effect of age on hallucination without mediator	indirect effect with anxiety as mediator	indirect effect with anxiety as mediator	difference between direct and indirect effect	effect size measure for mediation
Auditory	$b = -0.14$, $t(2422) = 7.38^{***}$ Model: $F(1,2422) = 54.40^{***}$, $R^2 = 0.02$	$b = 0.03$, $t(2422) = 8.97^{***}$ Model: $F(2,2421) = 68.32^{***}$, $R^2 = 0.05$	$b = -0.16$, $t(2422) = 8.48^{***}$	$b = 0.02$, Lower CI = 0.01, Upper CI = 0.03	$b^* = 0.02$, Lower CI = 0.01, Upper CI = 0.03
Visual	$b = -0.22$, $t(2422) = 7.16^{***}$ Model: $F(1,2422) = 55.53^{***}$, $R^2 = 0.02$	$b = 0.05$, $t(2422) = 9.24^{***}$ Model: $F(2,2421) = 71.38,^{***}$, $R^2 = 0.06$	$b = -0.25$, $t(2422) = 8.59^{***}$	$b = 0.03$, Lower CI = 0.02, Upper CI = 0.04	$b^* = 0.02$, Lower CI = 0.01, Upper CI = 0.03
Olfactory	$b = -0.27$, $t(2422) = 7.65^{***}$ Model: $F(1,2422) = 58.58^{***}$, $R^2 = 0.02$	$b = 0.06$, $t(2422) = 7.70^{***}$ Model: $F(2,2421) = 59.63^{***}$, $R^2 = 0.05$	$b = -0.31$, $t(2422) = 8.58^{***}$	$b = 0.03$, Lower CI = 0.02, Upper CI = 0.05	$b^* = 0.02$, Lower CI = 0.01, Upper CI = 0.03
Tactile	$b = -0.26$, $t(2422) = 8.09^{***}$ Model: $F(1,2422) = 65.53^{***}$, $R^2 = 0.03$	$b = 0.05$, $t(2422) = 7.10^{***}$ Model: $F(2,2421) = 58.63^{***}$, $R^2 = 0.05$	$b = -0.29$, $t(2422) = 8.94^{***}$	$b = 0.03$, Lower CI = 0.02, Upper CI = 0.04	$b^* = 0.02$, Lower CI = 0.01, Upper CI = 0.02
Hypnagogic/ hypnopompic	$b = -0.25$, $t(2422) = 8.37^{***}$ Model: $F(1,2422) = 70.03^{***}$, $R^2 = 0.03$	$b = 0.05$, $t(2422) = 8.00^{***}$ Model: $F(2,2421) = 67.90^{***}$, $R^2 = 0.05$	$b = -0.28$, $t(2422) = 9.34^{***}$	$b = 0.03$, Lower CI = 0.02, Upper CI = 0.04	$b^* = 0.02$, Lower CI = 0.01, Upper CI = 0.03
Sensed presence	$b = -0.14$, $t(2422) = 3.49^{***}$ Model: $F(1,2422) = 12.19^{***}$, $R^2 < 0.01$	$b = 0.04$, $t(2422) = 5.27^{***}$ Model: $F(2,2421) = 20.04$, $R^2 = 0.02$	$b = -0.17$, $t(2422) = 4.09^{***}$	$b = 0.02$, Lower CI = 0.01, Upper CI = 0.04	$b^* = 0.01$, Lower CI = 0.01, Upper CI = 0.02

Notes: CI = confidence interval (95%); * $p < .05$; ** $p < .01$; *** $p < .001$.

types (95% confidence bands did not overlap with zero, see Table 5). The effect sizes were, however, even lower than for anxiety (see Table 5). The mediation model with depression and age as predictors accounted for 2–6% of the variance in all hallucination measures, while age alone accounted for 2–3% in most cases.

3.4. *Effect of gender on mediation analyses*

When gender was entered as a covariate in the mediation analyses, the results hardly changed. The mediation model with *anxiety*, age, and gender as predictors accounted for 8–11% of the variance in all hallucination measures (age alone accounted for roughly 2–3%). These numbers are almost identical to the mediation analysis without gender as a covariate. Similarly, the mediation model with *depression*, age, and gender as predictors accounted for 5–6% of the variance in all hallucination measures (age alone accounted for roughly 2–3.5%). Again, these numbers are almost identical to the mediation analysis without gender as a covariate.

3.5. *Co-occurrence of unisensory hallucinations in the different modalities across age groups*

Fig. 3 shows the percentage of participants who experienced uni- and multi-sensory hallucinations for all three age groups. Important to note is that this was calculated based on those participants who answered positively (i.e. who answered 3 or 4 on the 5-point response scale for the respective item) on at least one modality-specific item.[1]

The percentage of individuals who had experienced hallucinations in all five modalities and sensed presence decreased with age, from 10.0% to 5.0% to 1.7% for the young, middle and old groups, respectively.

Regarding single modality experiences, a few tendencies were noted. The percentage of olfactory hallucinations was stable across age-groups from 10.8% to 10.8% to 11.4% for the young, middle, and old group, respectively. However, the percentage of people who have experienced a sensed presence increases with age from 12.3% to 20.1% to 29.8% for the young, middle and old group, respectively.

Concerning modalities that are associated with each other, it is interesting to note that there was little overlap between auditory and visual hallucinations (0.7%, 0.8%, 1.7% for the young, middle and old group, respectively). In contrast, sensed presence is often associated with olfactory hallucinations (3.8%, 6.4%, 5.3% for the young, middle and old group, respectively) and sensed presence is often associated with tactile hallucinations in all three age groups (3.1%, 3.3%, 2.6% for the young, middle and old group, respectively).

When comparing the hallucination modalities and types in the young group, the highest prevalence was: sensed presence, olfactory, followed by tactile and finally visual. In the middle group this was: sensed presence, olfactory, visual, tactile and auditory. Finally, in the old group this was: sensed presence, olfactory, visual, and equally tactile/auditory. The general trend across all three age-groups was thus that sensed presence is the highest followed by the olfactory modality. This was followed by the visual modality in the middle and old groups, but not in the young group where auditory was the third highest.

4. Discussion

The present study examined a potential age effect on hallucinations in a large, randomly selected and representative general population sample. This potential age effect was examined for different hallucination modalities and types including auditory, visual, olfactory, and

[1] Kindly note that this calculation contrasts with the calculations made in Table 2. In Table 2, the average score for each modality across all participants, including those who do not report hallucinations (i.e. score = 0), is reported.

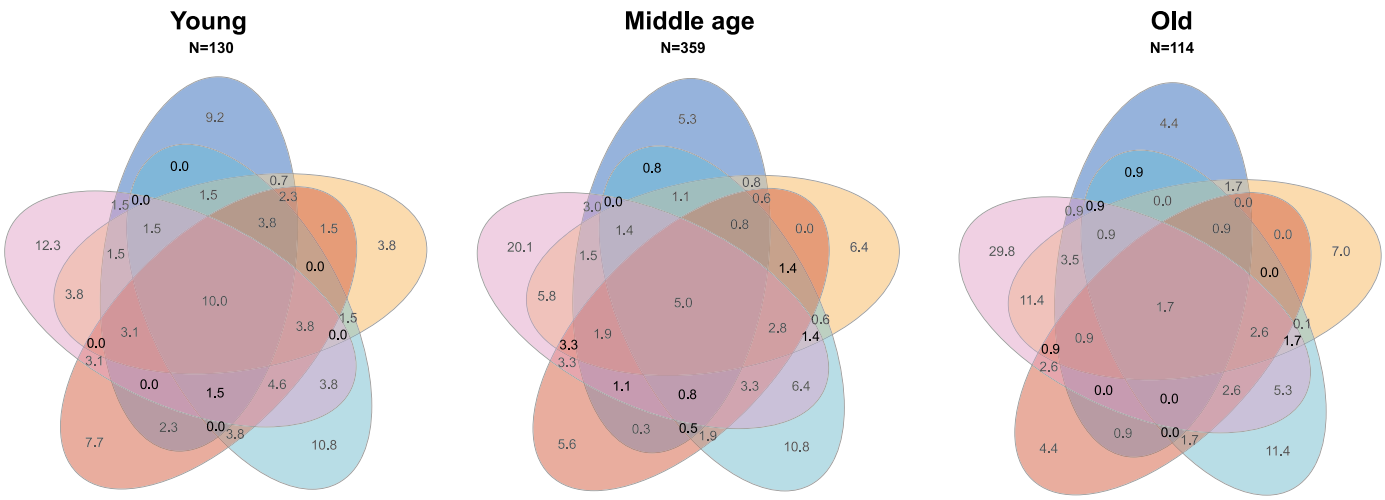

Fig. 3. Co-occurrence of hallucinations in different modalities across age groups.
Numbers are percentages. Blue = auditory; orange = visual; turquoise = olfactory;
red = tactile; pink = sensed presence. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

tactile modalities and sensed presence and hypnagogic/hypnopompic hallucinations.

Results revealed a significant main effect of age for all modalities, whereby hallucination prevalence significantly decreased with age. That is, prevalence rates were highest in young, followed by middle and then lowest in older adult group. This was the case for all hallucinations types and modalities, with the exception of sensed presence. That is, although there was a decrease in prevalence rates across age groups for sensed presence, there was only a significantly statistical difference between the young and the old age groups.

It is difficult to relate these findings to previous studies as this is the first time an age effect for hallucinations prevalence has been examined in the same epidemiological study. Thus, many more studies are clearly needed both in order to replicate this finding but also, and more importantly, in order to better understand what is underlying and driving the age effect. The meta-analysis by Maijer et al. (2018) suggested a general mean lifetime prevalence decrease across age (with children and adolescents reporting these experiences significantly more often compared with adults and the elderly). However, since this meta-analysis included studies using different methodologies, a certain degree of precaution is recommended. Badcock et al. (2017) reviewed studies that have examined prevalence rates of hallucinations in the general population albeit exclusively in healthy older adults (> 60 years of age) and observed that results from studies seem to suggest that prevalence rates of hallucinations decrease with age. However, it is important to mention that this was not always the case, and that there were very few studies in the literature that have examined this issue in general.

What may be driving or underlying this (potential) age effect? The present study also examined this issue, albeit only with two variables (degree of anxiety and depression). The examination of these was based on previous research (Larøi et al., 2005) suggesting that these variables might be involved in an age effect. The results revealed that the mediation model with anxiety and age as predictors accounted for 7–11% of the variance in all hallucination measures, while age alone accounted only for roughly 2–3%. Depression had a partially suppressive effect on the negative association between age and hallucinations, but had less impact than anxiety (accounting for ca. 2–6% of the variance). Future studies examining this issue are clearly needed and will need to examine other potential variables, in addition to degree of anxiety and depression. Furthermore, future studies will need to utilise different methodologies, such as a longitudinal design, in order to tease apart potential causal factors.

Concerning co-occurrence of hallucination modalities and sensed presence, it was observed that the percentage of people who have experienced these decreased with age. Whereas the prevalence of olfactory hallucinations was stable across age groups, the percentage of people who had experienced a sensed presence clearly increased with age. There was very little overlap between auditory and visual hallucinations in all three age groups. In contrast, sensed presence was often associated with other modalities (in particular, olfactory and tactile hallucinations) in all three age groups. Finally, for all three age groups, sensed presence had the highest prevalence followed by olfactory hallucinations.

Again, since this is the first time that these issues have been examined in the same epidemiological study, it is difficult to compare them with other studies. However, some of these findings can be compared with studies that have included patients. Concerning modalities that are associated with each other, it is interesting to note that there was very little co-occurrence of auditory and visual hallucinations in all three age groups (0.7%, 0.8%, 1.7%). This is in contrast with studies including patient groups, especially patients with schizophrenia where the most common modality is auditory, followed by visual (cf. Jablensky, 1997; Thomas et al., 2007; Llorca et al., 2016; McCarthy-Jones et al., 2017; for a review see Waters et al. (2014). For instance, McCarthy-Jones et al. (2017) observed that the majority of the patients with schizophrenia in their two samples (one from Ireland and one from the Australia) had only ever hallucinated in one modality, and this was most commonly the auditory modality (in 90% and 96% of patients, respectively). Further, around a third of patients in both samples had experienced hallucinations in two modalities, with the most common combination being the auditory and visual (in 67% and 66% of patients, respectively).

The general trend across all three age groups was that sensed presence was always the highest followed by olfactory. This is followed by visual in the middle and old group, but not in the young group where auditory is the third highest. This type of pattern is also different from what is observed in patients with schizophrenia where the typical pattern is that auditory hallucinations are the most prevalent, followed by visual hallucinations (Waters et al., 2014) and this pattern in patients with schizophrenia also seems to remain across cultures (for a review see Larøi et al., 2014). Thus, studies with patients with schizophrenia suggest a particular excess of auditory hallucinations in contrast to general population studies (such as the present study) where this auditory hallucinations excess is totally absent. Furthermore, it seems that the manifestation of hallucinations is more “diverse” (e.g. involves many more hallucination modalities) compared to clinical

populations (e.g. patients with schizophrenia). These contrasting patterns may be telling us something about different aetiologies. Clearly, future research is needed to replicate and further explain these effects.

The major limitations of our study are two-fold. Firstly, no strict diagnostic criteria were employed, for example, for hallucinations (confirming that the experience also has the full force of a true perception, excluding illusions and other related experiences, etc.) and for psychiatric illness (for example, in order to distinguish between those participants with a clinical diagnosis and those without a clinical diagnosis). However, this would have required adding a substantial number of additional questions to the questionnaire (which was already quite extensive) and/or carrying out a telephone interview, which was not feasible in the context of the present study. Secondly, the cross-sectional nature of the data precludes conclusions regarding causality.

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Conflict of interest

The authors declare that they have no conflict of interest.

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