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In the twilight zone: An epidemiological study of sleep-related hallucinations

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ABSTRACT

Background: Few studies have investigated hallucinations that occur at the onset/offset of sleep (called hypnagogic/hypnopompic hallucinations; HHHs), despite the fact that their prevalence in the general population is reported to be higher than the prevalence of daytime hallucinations. We utilized data from an epidemiological study to explore the prevalence of HHHs in various modalities. We also investigated phenomenological differences between sleep-related (HHHs) and daytime hallucinations in the auditory modality. We hypothesized that individuals with only HHHs would not differ from controls on a range of mental health and wellbeing measures, but that if they occur together with daytime hallucinations will pose a greater burden on the individual experiencing them. We also hypothesize that HHHs are qualitatively different (i.e. less severe) from daytime hallucinations.

Methods: This study utilized data from a cross-sectional epidemiological study on the prevalence of hallucinations in the Norwegian general population. The sample ($n = 2533$) was divided into a control group without hallucinations ($n = 2303$), a group only experiencing sleep-related hallucinations ($n = 62$), a group only experiencing daytime hallucinations ($n = 57$), and a group experiencing both sleep-related as well as daytime hallucinations ($n = 111$). Prevalence rates were calculated and groups were compared using analyses of variance and chi-square tests where applicable.

Results: The prevalence for HHHs in the auditory domain was found to be 6.8%, whereas 12.3% reported multimodal HHHs, and 32.2% indicated out-of-body experiences at the onset/offset of sleep. Group comparisons of hallucinations in the auditory modality showed that individuals that experienced only auditory HHHs scored significantly ($p < 0.05$) lower than those who also experienced daytime auditory hallucinations on a range of variables including mental health, anxiety, childhood happiness, and wellbeing. In addition, individuals with only auditory HHHs reported significantly ($p < 0.05$) less frequent hallucinations, less disturbing hallucinations, more neutral (in terms of content) hallucinations, hallucinations with less influence over their behavior, and less hallucination-related interference with social life compared to those individuals that experience daytime hallucinations. We also found that purely auditory HHHs had a significantly higher age of first onset of hallucinations than the purely daytime and the combined daytime and auditory HHHs groups (28.2 years>20.9 > 19.1).

Conclusions: Sleep-related hallucinations are common experiences in the general population, with the auditory modality being the least common. They occur mostly in combination with daytime hallucinations. However, some individuals (2.4%) experience only (auditory) sleep-related hallucinations and this group can be seen as more closely related, on a range of health-related factors, to non-hallucinating individuals than individuals who experience daytime hallucinations. Finally, there is a clear need for more research in this field, and ideas for future studies are presented.

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1. Introduction

Hallucinations are usually studied as a mental phenomenon that occurs during wakefulness. Lesser studied, yet more common in the general population, are hallucinations that occur in the borderline state between falling asleep and being awake, often referred to as hypnagogic (onset of sleep) and hypnopompic (upon awakening) hallucinations (HHHs), respectively [1,2]. In the present study we report on HHHs in the general population, which is an interesting phenomenon for a number of reasons. HHHs represent a particular type of hallucination, in a particular situational context, in which the brain is in an altered state of consciousness [see [3]]. Thus, studying HHHs may contribute to an increase in our knowledge of hallucinations in general, and also more specifically increase our knowledge of hallucinations as a symptom in mental disorders. Studying HHHs also represents a unique and rare opportunity to examine mental events that occur when the brain is in a transition from wakefulness to sleep, and from sleep to wakefulness.

In a telephone survey of a representative sample of the general population ($n = 4972$), Ohayon et al. [4] found that 37.0% of the sample reported hypnagogic hallucinations and 12.5% reported hypnopompic hallucinations (both multimodal), at least twice a week over the last year. Jones et al. [2], using a different questionnaire (the Durham Hypnagogic and Hypnopompic Hallucinations Questionnaire), found that 33.2% of their sample (college students) had experienced HHHs. As a comparison, regarding daytime hallucinations, Laloyaux et al. [5] (using the Launay-Slade Hallucination Scale (LSHS) [6]) reported a 7.0% prevalence rate of daytime hallucinations (across modalities) in the Norwegian general population. Thus, HHHs seem to be a more common phenomenon than daytime hallucinations. Although HHHs can occur independent from daytime hallucinations, they often seem to co-occur as reported by Ohayon [7]. In this extended sample ($n =$ 13,057), 24.1% of individuals with daytime hallucinations also reported having hypnagogic hallucinations and 17% reported having hypnopompic hallucinations.

As mentioned above, HHHs occur across sensory modalities. Waters et al. [8] report that visual phenomena in some studies constitute up to 86% of HHHs and typically consist of kaleidoscopically changing visual perceptions such as geometric patterns, shapes and light flashes. Furthermore, somatic experiences, including bodily distortions, feelings of weightlessness, flying or falling, and a sense of presence in the room, occur in up to 44% of reported cases, while voices and other sounds (phone, doorbell, music) appear to be less common (up to 34% of reported cases) (see Waters et al. [8]). In order to allow to compare with previous reports, we investigated prevalence rates for different sensory modalities, i.e. auditory, out-of-body, and multimodal HHHs.

In addition to prevalence rates, we were also interested in understanding potential differences between individuals with only auditory HHHs (aHHHs) compared to individuals with a) neither sleep-related (aHHHs) nor daytime auditory verbal hallucinations (AVHs), (b) only daytime AVHs, and (c) both aHHHs and daytime AVHs. This issue has not been investigated previously. Following the continuum model of psychosis [9], we expect hallucinations to be distributed among the general population in various degrees of severity, from less severe, isolated aHHHs to more severe hallucinations when co-occurring with daytime hallucinations. Thus, it was hypothesized that individuals with only aHHHs would not differ significantly from individuals with neither aHHHs nor daytime AVHs. Further, we expected individuals with only aHHHs to report less severe mental health issues and less severe hallucination-characteristics (measured by e.g. frequency, valence, level of disturbance), compared to the other hallucination groups, especially when compared with the group with combined aHHHs and daytime AVHs. This is based on the assumption that isolated aHHHs (i.e. without the presence of daytime AVHs) occur in a transitory state from wakefulness to sleep, and from sleep to wakefulness, and as such may be regarded as a common epiphenomenon of the complex interplay between cholinergic and aminergic neurochemical systems rather than being part of a primary pathology.

2. Methods

2.1. Sample

This study utilized data from a cross-sectional epidemiological study on the prevalence of AVHs in the Norwegian general population [see [10]]. In order to avoid cultural and language differences that could have confounded results, participants had to be able to speak and understand Norwegian, and be born, raised, and currently living in Norway. In total, 8000 individuals aged 18 years and older were invited to participate via a postal questionnaire. A total of 169 individuals could not be reached and 11 individuals did not wish to participate in the study, leaving 7820 individuals who were contacted and did not explicitly decline to participate. Of these 7820 individuals, 2533 (32.4%) completed and returned the questionnaire, and therefore formed the final study sample [see [10] for further details].

For the purpose of the present study, the original sample was divided into four independent sub-groups depending on their answers to three items of the Launay-Slade Hallucination Scale (LSHS), whereby two items deal with daytime AVHs (items 4 and 8) and one item deals with HHHs (modified item 11). The latter item was split into auditory and multisensory modalities in order to differentiate between modalities. The four independent sub-groups were as follows:

1) Participants who did not answer affirmatively (i.e. who responded, "Certainly does not apply to me" or "Possibly does not apply to me" or "Unsure") to both daytime AVH and auditory HHH (aHHH)-items. This sub-group is called the *Control group* and consisted of 2303 participants.
2) Participants who answered *affirmatively* (i.e. who responded, "Possibly applies to me" or "Certainly applies to me") to the item about aHHHs (modified item 11 of the LSHS: "Sometimes, right before I fall asleep or wake up, I have had the experience of hearing a voice, even though no one was there.") *but not affirmatively* ("Certainly does not apply to me" or "Possibly does not apply to me" or "Unsure") to the items about daytime AVHs (item 4 of the LSHS: "In the past I have had the experience of hearing a person's voice and then found that there was no-one there" and/or item 8 of the LSHS: "I often hear a voice speaking my thoughts aloud"). This sub-group is called the *aHHH group* and consisted of 62 participants.
3) Participants who answered *affirmatively* (i.e. who responded, "Possibly applies to me" or "Certainly applies to me") to the items about daytime AVHs (item 4 of the LSHS: "In the past I have had the experience of hearing a person's voice and then found that there was no-one there" and/or item 8 of the LSHS: "I often hear a voice speaking my thoughts aloud") *but not affirmatively* ("Certainly does not apply to me" or "Possibly does not apply to me" or "Unsure") to the item about aHHHs (modified item 11 of the LSHS: "Sometimes, right before I fall asleep or wake up, I have had the experience of hearing a voice, even though no one was there."). This sub-group is called the *AVH group* and consisted of 57 participants.
4) Participants who answered *affirmatively* (i.e. who responded, "Possibly applies to me" or "Certainly applies to me") to the item about aHHHs (modified item 11 of the LSHS: "Sometimes, right before I fall asleep or wake up, I have had the experience of hearing a voice, even though no one was there.") *as well as affirmatively* ("Possibly applies to me" or "Certainly applies to me") to the questions about daytime AVHs (item 4 of the LSHS: "In the past I have had the experience of hearing a person's voice and then found that there was no-one there" and/or item 8 of the LSHS: "I often hear a voice speaking my thoughts aloud"). This sub-group is called the *AVH + aHHH* group and consisted of 111 participants.

2.2. Questionnaire

Prevalence rates were calculated based on the following sleep-related LSHS items:

1) aHHH (modified item 11 of the LSHS: "Sometimes, right before I fall asleep or wake up, I have had the experience of hearing a voice, even though no one was there.")
2) out-of-body HHH (item 12 of the LSHS: "Sometimes, right before I fall asleep or wake up, I have felt like I am floating or falling, or temporarily leaving my body")
3) multimodal HHH (modified item 11 of the LSHS: "Sometimes, right before I fall asleep or wake up, I have had the experience of seeing or feeling something that was not there, or felt like someone had touched me, even though no one was there")

Differences between the four independent sub-groups regarding clinical features were explored based on questions regarding:

1) Physical health ("How is your physical health?")
2) Mental health ("How is your mental health?")
3) Hospital Anxiety and Depression Scale [HADS; [11]], which is a fourteen-item questionnaire that measures the severity of anxiety and depression. Each item is rated on a four-point response scale, generating a total score ranging from 0 to 21.
4) Adverse life events ("Have you ever experienced a decisive adverse event in your life such as death in the near family, accident, catastrophe, abuse, war, divorce/break-up, or bullying?")
5) Considered contacting a health professional due to psychological issues ("Have you ever considered contacting a psychologist, medical doctor, or similar, due to psychological issues?")
6) Intake of medication because of psychological issues ("Have you used any medication for psychological problems?")
7) Use of alcohol (frequency) ("How often do you drink alcohol?")
8) General wellbeing ("How would you describe your general condition?")
9) Childhood happiness ("When thinking about your childhood/upbringing, you would describe it as…")

Differences between the three independent hallucination subgroups were explored with regard to additional questions about hallucination-characteristics:

1) Age of onset ("How old were you the first time you heard voices?")
2) Frequency ("Approximately how often do you hear voices?")
3) Valence ("The voices are experienced mainly as…")
4) First-onset trigger ("What situation were you in when you first started hearing voices"?)
5) Influence of hallucinations over one's behavior ("Have you allowed the voices to influence your behavior?")
6) Interference of hallucinations with social contacts ("Do the voices interfere with your social interactions?")
7) Level of disturbance of hallucinations ("I have been troubled by hearing voices in my head"; item 9 of the LSHS)

Table 1
Sociodemographic group characteristics.

	Control	aHHH	AVH	AVH + aHHH
N	2303 (SD)	62 (SD)	57 (SD)	111 (SD)
Age (years)	50.2 (±16.2)	49.7 (±16.1)	43.6 (13.8)	41.5 (16.3)
Age at first onset of voices (years)	–	28.2 (±16.4)	20.9 (15.0)	19.1 (13.1)
	% (*N*)	% (*N*)	% (*N*)	% (*N*)
Sex				
Male	45.8 (1054)	46.8 (29)	49.1 (28)	35.1 (39)
Female	54.2 (1249)	53.2 (33)	50.9 (29)	64.9 (72)
Marital status				
Unmarried/not cohabitant	14.5 (335)	16.1 (10)	22.8 (13)	31.5 (35)
Married	54.2 (1249)	38.7 (24)	43.9 (25)	27.0 (30)
Cohabitant	18.6 (428)	24.2 (15)	22.8 (13)	25.2 (28)
Widow/er	4.3 (100)	4.8 (3)	1.75 (1)	4.5 (5)
Separated/divorced	6.9 (158)	16.1 (10)	8.8 (5)	10.8 (12)
Registered partnership	0.2 (5)	0 (0)	0 (0)	0 (0)
Living status				
Alone	16.9 (390)	27.4 (17)	17.5 (10)	22.5 (25)
With spouse/partner or other adult	40.3 (929)	37.1 (23)	50.9 (29)	32.4 (36)
Alone with child/children	3.1 (72)	3.2 (2)	5.3 (3)	9.0 (10)
With spouse/partner and child/children	33.7 (777)	25.8 (16)	19.3 (11)	22.5 (25)
With other adults and own children	0.6 (13)	0 (0)	0 (0)	0 (0)
Other	4.6 (105)	6.4 (4)	7.0 (4)	11.7 (13)
Highest educational level				
Primary school	17.0 (391)	16.1 (10)	10.5 (6)	12.6 (14)
Vocational school	23.7 (546)	21.0 (13)	24.6 (14)	22.5 (25)
Secondary school	12.7 (293)	11.3 (7)	15.8 (9)	17.1 (19)
College	21.7 (499)	24.2 (15)	29.8 (17)	30.6 (34)
University (4 years or more)	24.5 (564)	27.4 (17)	19.3 (11)	16.2 (18)
Occupation				
Employed	60.5 (1393)	56.4 (35)	56.1 (32)	45.0 (50)
Social welfare	24.5 (565)	32.3 (20)	24.6 (14)	23.4 (26)
Self-employed	5.2 (119)	6.4 (4)	5.3 (3)	5.4 (6)
Unemployed	1.5 (35)	0 (0)	1.7 (1)	4.5 (5)
Full-time domestic work	0.6 (15)	0 (0)	0 (0)	0.9 (1)
Student/military service	3.9 (90)	3.2 (2)	7.0 (4)	11.7 (13)
Other	3.3 (77)	1.6 (1)	5.3 (3)	8.1 (9)
Family history of AVH				
Yes	–	17.7 (11)	12.3 (7)	24.3 (27)
No	–	21.0 (13)	21.0 (12)	8.1 (9)
Don't know	–	48.4 (30)	59.6 (34)	54.9 (61)

aHHH: auditory hypnogogic and hypnopompic hallucinations; AVH: auditory verbal hallucinations; H: health; LE: life events.

Table 2
Analyses of variance (ANOVAs) comparing the four sub-groups on general health and wellbeing variables.

	Control	aHHH	AVH	AVH + aHHH	F (df)	*p*
	N = 2303	*N* = 62	*N* = 57	*N* = 111		
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)		
Physical H	2.99 (0.01)[a]	2.81 (0.09)[a, b]	2.95 (0.08)[a, b]	2.74 (0.08)[b]	6.08 (32522)	<0.001
Mental H	3.29 (0.01)[a]	3.19 (0.11)[a]	3.04 (0.10)[a, b]	2.86 (0.09)[b]	14.29 (32532)	<0.001
Anxiety	11.40 (0.1)[a]	12.25 (0.49)[a, b]	13.42 (0.55)[b, c]	14.46 (0.42)[c]	34.22 (32452)	<0.001
Depression	10.03 (0.06)[a]	10.43 (0.46)[a, b]	11.05 (0.53)[a, b]	11.41 (0.40)[b]	9.10 (32485)	<0.001
Adverse LE	1.42 (0.02)[a]	1.77 (0.12)[b]	1.84 (0.15)[b]	1.94 (0.12)[b]	13.67 (32503)	<0.001
Alcohol	3.20 (0.03)[a]	3.39 (0.18)[a]	3.02 (0.17)[a]	3.00 (0.13)[a]	1.57 (32518)	=0.206
Childhood	1.81 (0.02)[a]	1.95 (0.13)[a]	2.00 (0.13)[a, b]	2.39 (0.13)[b]	13.27 (32516)	<0.001
Wellbeing	2.34 (0.02)[a]	2.50 (0.12)[a]	2.49 (0.14)[a]	2.94 (0.12)[b]	12.34 (32520)	<0.001

aHHH: auditory hypnogogic and hypnopompic hallucinations; AVH: auditory verbal hallucinations; H: health; LE: life events.
Same superscript letter indicates no significant difference between groups; different superscript letter indicates significant difference between groups ($p < 0.05$).

8) Contact with a health professional because of hallucinations ("Have you ever contacted a psychologist, medical doctor, or similar, due to a problematic relationship with the voices?")
10) Intake of medication because of hallucinations ("Have you used medication for the voices you hear?")

2.3. Statistical analysis

Differences between the groups were evaluated statistically using one-way analyses of variance (ANOVAs), and significant effects were followed up with post-hoc *t*-tests ($p < 0.05$; Bonferroni correction was used to control for multiple comparisons). For testing relationships between groups on categorical variables, the chi-square test was used. Differences were regarded as significant for $z > 1.96$.

2.4. Ethical standards

The study was approved by the Regional Committee for Medical Research Ethics in Central Norway (REC-Central) and all participants gave their informed consent prior to their inclusion in the study.

3. Results

3.1. Prevalence of sleep-related hallucinations

In the sample of 2533 individuals who returned the questionnaire, 6.8% ($n = 173$) reported having experienced aHHHs, 12.3% ($n = 312$) reported having had multimodal HHHs, and 32.2% ($n = 816$) indicated that they had experienced out-of-body HHHs at least once in their lifetime. Of those individuals reporting aHHHs ($n = 173$), 64.2% ($n = 111$) reported daytime AVHs as well. Individuals who reported aHHHs without daytime AVHs, accounted for 2.4% ($n = 62$) of the overall sample, while individuals who reported daytime AVHs without aHHHs comprised 2.2% ($n = 57$) of the overall sample (Table 1).

3.2. Differences between all four sub-groups with regard to general health and wellbeing

The one-way ANOVAs showed significant main effects for all general health and wellbeing variables except for frequency of alcohol consumption (see Table 2). Post-hoc analyses revealed that the Control group reported better physical and mental health, lower anxiety and depression scores, fewer adverse life events, a happier childhood, and better general wellbeing, compared to the AVH + aHHH group. The Control group also reported lower anxiety scores compared to the aHHH group and fewer adverse life events compared to both the aHHH group and the AVH group. In addition, the aHHH group reported significantly better mental health, lower anxiety scores, a happier childhood, and better general wellbeing than the AVH + aHHH group. Finally, the AVH group reported better general wellbeing than the AVH + aHHH group. See Table 2 for main effects and post-hoc effects.

Results from the chi-square tests (Table 3) showed that the Control group included a significantly lower percentage of participants that had considered or were considering contacting a health professional for mental health problems, compared to the AVH + aHHH group. Also, a higher percentage of control group participants rated this question as not applicable compared to the other groups. With regard to medication, a significantly lower percentage of participants in the Control group indicated that they had taken medication for mental health issues compared to the AVH and AVH + aHHH groups. Also, a significantly higher percentage of participants in the Control indicated that the question was not applicable to them compared to the respective percentage in the aHHH and AVH + aHHH groups.

3.3. Differences between the three hallucination sub-groups with regard to AVH-related variables

A one-way ANOVAs showed significant main-effects of frequency of AVHs, influence of AVHs over one's behavior, interference of AVHs with social contacts, and level of disturbance of AVHs. Post-hoc tests revealed that the aHHH group reported significantly less frequent hallucinations, less disturbing hallucinations, hallucinations with less influence over their behavior, and hallucinations with less interference with social contacts compared to the AVH group and the AVH + aHHH group (see Table 4).

The chi-square results (see Table 5) showed that the aHHH group included a significantly higher percentage of participants who reported

Table 3
Chi-square analyses comparing the four sub-groups on general health variables.

	Control	aHHH	AVH	AVH + aHHH
	N = 2303	*N* = 62	*N* = 57	*N* = 111
	% (*N*)	% (*N*)	% (*N*)	% (*N*)
Contact HP				
Yes, now	5.9 (135)[a]	12.9 (8)[a,b]	10.5 (6)[a,b]	13.5 (15)[b]
Yes, before	19.6 (452)[a]	21.0 (13)[a,b]	36.8 (21)[b]	38.7 (43)[b]
No, never	29.1 (670)[a]	38.7 (24)[a]	33.3 (19)[a]	34.2 (38)[a]
N/A	44.6 (1027)[a]	27.4 (17)[b]	19.3 (11)[b]	12.6 (14)[b]
Medication				
Yes, now	4.8 (111)[a]	9.7 (6)[a,b]	15.8 (9)[b]	11.7 (13)[b]
Yes, before	8.4 (194)[a]	12.9 (8)[a,b]	15.8 (9)[a,b]	16.2 (18)[b]
No, never	42.7 (983)[a]	51.6 (32)[a]	42.1 (24)[a]	54.1 (60)[a]
N/A	43.6 (1005)[a]	25.8 (16)[b]	26.3 (15)[a,b]	17.1 (19)[b]

aHHH: auditory hypnogogic and hypnopompic hallucinations; AVH: auditory verbal hallucinations; HP: health professional.
Same superscript letter indicates no significant difference between groups; different superscript letter indicates significant.
percentage-difference between groups ($z > 1.96$).

Table 4
Analyses of variance (ANOVAs) comparing the three AVH sub-groups on AVH-related variables.

	aHHH	AVH	AVH + aHHH	F (df)	*p*
	N = 62	*N* = 57	*N* = 111		
	Mean (SE)	Mean (SE)	Mean (SE)		
Frequency	1.50 (0.11)[a]	2.36 (0.19)[b]	2.50 (0.13)[b]	13.12 (2202)	$p < 0.001$
Influence	2.85 (0.06)[a,b]	2.48 (0.09)[b]	2.35 (0.07)[b]	11.72 (2199)	$p < 0.001$
Interference	3.00 (0.00)[a,b]	2.78 (0.46)[b]	2.72 (0.54)[b]	7.11 (2199)	$p < 0.01$
Disturbance	0.13 (0.07)[a]	0.81 (0.18)[b]	1.70 (0.16)[c]	26.96 (2222)	$p < 0.001$

aHHH: auditory hypnogogic and hypnopompic hallucinations; AVH: auditory verbal hallucinations.
Same superscript letter indicates no significant difference between groups; different superscript letter indicates significant. difference between groups ($p < 0.05$).

voices with neutral valence compared to the AVH + aHHH group. Also, there was a significantly lower percentage of participants who indicated a first-onset trigger event in the aHHH group compared to the AVH + aHHH group. With regard to AVH-related contact with health professionals, a significantly lower percentage of aHHH participants indicated previous contact, and a significantly higher percentage of aHHH participants rated the question as not applicable to them, compared to the AVH + aHHH group. Finally, a significantly higher percentage of participants from the aHHH group rated the voice-related use of medication question as not applicable to them.

3.4. Differences in age at first onset

A one-way ANOVA showed a significant main-effect of age at first onset [$F(3, 174) = 5.85$, $p < 0.01$]. The post-hoc analysis revealed that the aHHH group was significantly older at first onset of voices (28.2 years) than both the AVH + aHHH group (19.1 years; $p < 0.01$) and the AVH group (20.9 years; $p < 0.05$).

Table 5
Chi-square analyses comparing the three AVH sub-groups on AVH valence, first-onset trigger, contact with health professional regarding AVHs, and use of medication for AVHs.

		aHHH	AVH	AVH + aHHH
		N = 62	*N* = 57	*N* = 111
		% (*N*)	% (*N*)	% (*N*)
AVH valence				
Positive	Yes	12.9 (8)[a]	17.5 (10)[a]	20.7 (23)[a]
	No	87.1 (54)[a]	82.5 (47)[a]	79.3 (88)[a]
Negative	Yes	4.8 (3)[a]	12.3 (7)[a]	9.0 (10)[a]
	No	95.2 (59)[a]	87.7 (50)[a]	91.0 (101)[a]
Positive/Negative	Yes	21.0 (13)[a]	24.6 (14)[a]	33.3 (37)[a]
	No	79.0 (49)[a]	75.4 (43)[a]	66.7 (74)[a]
Neutral	Yes	45.2 (28)[a]	40.4 (23)[a,b]	25.2 (28)[b]
	No	54.8 (34)[a]	59.6 (34)[a,b]	74.8 (83)[b]
Other*	Yes	09.7 (6)[a]	5.3 (3)[a]	13.5 (15)[a]
	No	90.3 (56)[a]	94.7 (54)[a]	86.5 (96)[a]
First-onset trigger	Yes	35.5 (22)[a]	49.1 (28)[a,b]	55.0 (61)[b]
	No	50.0 (31)[a]	42.1 (24)[a,b]	31.5 (35)[b]
Contact HP for AVH				
Yes. now		0.0 (0)[a]	5.3 (3)[a]	2.7 (3)[a]
Yes. before		1.6 (1)[a]	10.5 (6)[a,b]	19.8 (22)[b]
No. never		54.8 (34)[a]	52.6 (30)[a]	52.3 (58)[a]
N/A		41.9 (26)[a]	31.6 (18)[a,b]	23.4 (26)[b]
Medication AVH				
Yes		0.0 (0)[a]	8.8 (5)[a]	8.1 (9)[a]
No		54.8 (34)[a]	54.4 (31)[a]	64.0 (71)[a]
N/A		45.2 (28)[a]	36.8 (21)[a,b]	27.0 (30)[b]

aHHH: auditory hypnogogic and hypnopompic hallucinations; AVH: auditory verbal hallucinations; HP: health professional.
Same superscript letter indicates no significant percentage-difference between groups; different superscript letter indicates significant percentage-difference between groups ($z > 1.96$).
* This category included specific examples of voice content, which could be positive, negative or neutral.

4. Discussion

In this general population sample, multimodal and out-of-body HHHs were found to be more common than aHHHs (12.3% and 32.2% compared to 6.8%). This is in line with previous HHH-studies in the general population [see [7,12]] and these findings are contrasting to findings concerning daytime hallucinations in schizophrenia patients where the auditory modality is dominant [13]. Also, aHHHs occurred mostly (64.2%) in combination with daytime AVHs and vice versa (66.1%), whereas isolated aHHHs (2.4%) and isolated daytime AVHs (2.2%) were both seldom reported. In line with these findings, other studies have found that hallucinations often occur in more than one modality in individuals in the general population, while unimodal hallucinations are more infrequent [5,14].

As hypothesized, the aHHH group did not differ significantly from the non-hallucinating control group for any of the general health parameters. On the other hand, the aHHH group showed better mental health in several domains (e.g. mental health, childhood happiness, subjective wellbeing, anxiety) than the AVH + aHHH group. In fact, the results revealed a continuous increase of severity from the aHHH group to the AVH group and further to the AVH + aHHH group. This may point to a developmental process, with isolated aHHH as a potential starting point for developing daytime hallucinations, for example, being triggered by an adverse life event [cf. [15]]. However, a different explanation is probably required when taking into account the results regarding age of onset. Here, individuals appear to develop daytime AVHs or combined AVH + aHHH at an earlier stage in life, suggesting different symptom trajectories for only sleep-related (i.e. aHHH) versus daytime AVHs or combined AVH + aHHH. It remains unknown, however, whether the occurrence of combined AVH + aHHH leads to more mental health problems or vice versa. Nevertheless, while it was known from previous studies that daytime AVHs were associated with various mental health problems, the present study was able to show that individuals with only aHHH were not any different from individuals without hallucinations (neither daytime nor sleep-related) on most general health parameters except for adverse life events, which occurred more often in the hallucination groups.

Furthermore, as hypothesized, the hallucination group with the significantly least severe hallucination-characteristics (measured by e.g. frequency, valence, level of disturbance) was the aHHH group. Similar to the general health parameters, we found a continuous increase of severity from the aHHH group to the AVH group and further to the AVH + aHHH group with regard to hallucination-characteristics. This suggests that when daytime and sleep-rated auditory hallucinations co-occur, the hallucinations are the most debilitating. More research is needed to shed light on when daytime and sleep-related auditory hallucinations occur together, especially since they appear to have a different trajectory than isolated aHHHs. Finally, it should be noted that all three hallucination groups are non-clinical groups, which means they have not received a diagnosis. At the same time, the results point towards the AVH + aHHH group being the most prone to general health problems,

whereas the aHHH group did not differ significantly from the non-hallucinating control group except for adverse life events, which were more frequent in the aHHH group.

There are some limitations to the present study. Sleep disorders were not assessed even though HHHs are common in narcolepsy (ICSD-3; [16]), among persons with symptoms of insomnia and excessive daytime sleepiness [4] and may also occur as part of sleep paralysis at sleep onset [17]. HHHs related to specific sleep disorders may represent qualitatively different experiences compared to HHHs not related to sleep disorders. Another limitation is related to the fact that the HHHs were not assessed separately (i.e. hypnagogic separate from hypnopompic experiences) although there is some evidence that they represent qualitatively different phenomena [e.g. [4,18]].

There are few studies on HHHs in general, and thus several questions remain to be addressed and they need to be rigorously examined in future studies. For instance, does degree of sleep quality (as assessed by using separate sleep measurements such as subjective questionnaire data and objective sleep sensor data, cf. [19]) have an effect on sleep-related hallucinations? Related to this, could interventions addressing sleep problems affect how troublesome the hallucinations are? Which neurobiological changes are occurring during the transition from wakefulness to sleep and from sleep to wakefulness that may contribute to producing HHHs? Do events during daytime play a role in the incidence and content of HHHs (perhaps especially in hypnagogic hallucinations)? Finally, are individual differences (e.g. suggestibility, personality traits, absorption) involved in determining the incidence and/or nature of HHHs?

Declaration of competing interest

The authors declare no conflict of interest.

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