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Source Monitoring in Hearing Impaired Individuals Experiencing Auditory Hallucinations

Master thesis Neuropsychology

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Abstract

Introduction: The process in which pieces of information are attributed to different sources is called source monitoring. A current hypothesis in schizophrenia is that deficits in source monitoring result in self-generated information being attributed to an external source (externalizing bias), resulting in auditory hallucinations. This hypothesis has not been investigated in other hallucinating populations, like hearing impaired individuals with hallucinations. In this study, a sample of hearing impaired individuals is studied to see if an externalizing bias can be found in Hallucinating Hearing impaired Individuals (HHI), compared to Non-hallucinating Hearing impaired Individuals (NHI). **Methods**: The Source Recognition Task (SRT) was used as a measure of source monitoring, where participants have to attribute information acquired earlier to either 'self', 'other' or 'new'. Then, the number of correct answers and the number of externalizing mistakes were compared between HHI and NHI. Then it was examined if severity of hallucinations can be associated with general source monitoring abilities and the externalizing bias. **Results**: No differences were found between HHI and NHI in correct answers or in externalizing mistakes. However, the severity of auditory hallucinations could partly predict the degree of the externalizing bias. **Discussion**: No differences between HHI and NHI could be found in general source monitoring or in externalizing bias. Even though a link was found between severity of hallucinations and the externalizing bias, this seems to suggest that the externalizing bias does not play a role in the origins of auditory hallucinations. This indicates different mechanisms underlie auditory hallucinations in schizophrenia and hearing impairment.

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Introduction

Everyone occasionally forgets where they have learned about a certain piece of information. One can, for instance, forget whether they heard a story from a friend, or if they read about it somewhere. Being able to remember the source of certain information is called source memory. The process through which different sources are distinguished is often called source monitoring (Johnson, Hashtroudi, & Lindsay, 1993). Making mistakes in this process can result in a false attribution of information. This is something that happens frequently and is associated with older age, higher stress levels and decreased concentration (Kreutzer, DeLuca & Caplan, 2011). However, source monitoring is also involved in distinguishing internally generated information from information presented in the outside world (Garrison, Bond, Gibbard, Johnson, & Simons, 2017; Johnson, Raye, Foley & Foley, 1981). When errors occur in this process, it can become difficult to distinguish dreams or imagined information from reality. It is theorized that systematically attributing self-generated information to an external source, also called an externalizing bias, can result in self-generated inner speech being interpreted as an external voice, i.e. a verbal auditory hallucination (Bentall, 1990; Johnson, et al., 1993; Simons, Garrison & Johnson, 2017). Throughout literature, several theories exist about the origins of auditory hallucinations, although the theory of the externalizing bias is currently one of the main hypotheses (Moseley, Fernyhough, & Ellison, 2013; Waters, et al., 2012).

Hallucinations are commonly known as a symptom of schizophrenia, and over the years, many studies have tried to investigate the association between source monitoring and hallucinations in schizophrenia patients. Different results can be found, associating schizophrenia patients with decreased general source monitoring abilities (Anselmetti, et al., 2005; Brébion, Gorman, Amador, Malaspina, & Sharif, 2002; Keefe, Arnold, Bayen, McEvoy, & Wilson, 2002; Stephane, Kuskowski, McClannahan, Surerus, & Nelson, 2010), or specifically associating them with an externalizing bias (Brébion, et al., 2000; Fisher, McCoy, Poole, & Vinogradov, 2008). Even individuals at risk for psychosis (meaning they experience early signs or symptoms) have been shown to have more difficulty identifying the source of auditory information (Johns, et al., 2010). However, all these studies mentioned above have only compared schizophrenia patients with healthy participants without schizophrenia, yet not all schizophrenia patients hallucinate. No distinction was made between hallucinating and non-hallucinating schizophrenia patients. Deficits in source monitoring and the externalizing bias might thus be symptoms of schizophrenia, perhaps associated with impaired cognition (Schaefer, Giangrande, Weinberger, & Dickinson, 2013), instead of being associated with the phenomenon of experiencing auditory hallucinations. This seems to be confirmed by one of the few studies that did compare hallucinating and non-hallucinating schizophrenia patients. Here, differences in source monitoring that were found between these groups, disappeared after controlling for verbal IQ and verbal memory (Seal, Crowe, & Cheung, 1997). However, another study did find an externalizing bias in hallucinating schizophrenia patients, compared to non-hallucinating schizophrenia patients (Brunelin, et al., 2006). This ambiguity makes it unclear if decreased source monitoring might be a symptom of schizophrenia, or if it can be identified as an underlying factor in the origins of auditory hallucinations.

However, many other (psychiatric) populations are also known to hallucinate, yet no studies have been performed to investigate if decreased source monitoring or an externalizing bias can also be associated with (the origins of) auditory hallucinations in these populations. Even in healthy individuals hearing voices is not uncommon (Beavan, Read, & Cartwright, 2011). Linszen, et al. (under review) found that of their sample of the general population, 5.8% had experienced auditory hallucinations in the last four weeks. Another population that is known to hallucinate consists of individuals with hearing impairment (Linszen, et al., under review; Teunisse, & Olde Rikkert, 2002). Hearing impairment in general has even been identified as a risk factor for psychosis (Linszen, Brouwer, Heringa, & Sommer, 2016). The previously mentioned study by Linszen, et al. (under review) also investigated the prevalence of auditory hallucinations in 829 hearing impaired adults. They found that in the last four weeks, 16.3% of their hearing impaired sample had experienced auditory hallucinations (Linszen, et al., under review). Next to hearing voices, musical hallucinations are particularly common in this population, taking the form of songs, melodies or childhood rhymes (Atkinson, 2006; Berrios, 1990; Cole, Dowson, Dendukuri, & Belzile, 2002; Evers, 2006; Griffiths, 2000; Hammeke, McQuillen, & Cohen, 1983). However, no research has yet focused on determining if auditory hallucinations in the hearing impaired population can be associated with decreased source monitoring as well.

In this study, we investigated if hearing impaired individuals that experience auditory hallucinations have decreased source monitoring in general, compared to those who do not hallucinate. Additionally, we investigated if an externalizing bias could be found in hearing impaired individuals with, compared to those without auditory hallucinations. We expected to find decreased source monitoring abilities, and more specifically, to find an externalizing bias in hearing impaired patients with auditory hallucinations. This would then provide evidence for the theory that source monitoring could play a role in the origins of auditory hallucinations. Additionally finding decreased source monitoring in the hearing impaired population may indicate a common mechanism between auditory hallucinations in hearing impairment and schizophrenia. Furthermore, finding out more about source monitoring in these populations could help provide information about auditory hallucinations across diagnoses, and perhaps help identify specific factors that contribute to experiencing auditory hallucinations in general.

A second aim of this study was to examine whether the severity of hallucinations can be predictive of the extent to which source monitoring is decreased, and the extent to which an externalizing bias can be identified. When severity of hallucinations increases, we expect to find a greater externalizing bias.

Methods

Participants

Participants were recruited from the database of a study called Understanding Hallucinations (UH), for which written consent was acquired. For UH, hearing impaired individuals were approached after they had an appointment at the Audiology department of the University Medical Center Utrecht (UMCU). Here, a short questionnaire was used to screen patients on a number of properties, among which the severity of the hearing impairment and the presence of hallucinations. If they were eligible and willing to participate, they were either assigned to the hallucinating or the non-hallucinating group. Participants in the hallucinating group experienced complex auditory hallucinations at least once a month, and may hallucinate in other modalities as well (visual, tactile, olfactory). In contrast, participants in the non-hallucinating group were not allowed to have hallucinated more than twice during their life. If they did, this must be more than 2 years prior to participating, and be attributable to special circumstances (e.g. experiencing a delirium after surgery). Further inclusion criteria were that participants had to be at least 18 years of age, had to have a diagnosis of hearing impairment with a hFI (high Fletcher Index) of 25 dB or more in at least one ear, spoke adequate Dutch, and were mentally competent enough to understand the purpose of the study and to give informed consent. In total, 102 individuals with hearing impairment were included in this study, of which 56 were Hallucinating Hearing impaired Individuals (HHI) and 46 were Non-hallucinating Hearing impaired Individuals (NHI). While selecting data, four participants were excluded because they did not hallucinate frequently enough at the time of participation.

Task and Stimuli

Only three tests were used from the original UH protocol: the Source Recognition Task, QPE and MMSE. In total, a visit took between 2 and 2.5 hours. Patients did not receive an incentive for their participation, although their traveling costs were reimbursed.

Source Recognition Task

The task used to measure source monitoring was the Source Recognition Task (Vinogradov, et al., 1997; Mitchell, Hunt, & Schmitt, 1986). It consisted of two separate parts of administration. During the first part, 20 short sentences (e.g. "the lion ate the meat”) had to be read aloud by the participants. Half of these were already complete sentences, and in the other half the last word of the sentence was left blank, and the participant had to finish the sentence with a self-generated word. Approximately 45 minutes after the first part of the Source Recognition Task, the second part was administered, which consisted of an unannounced recall. Patients then had to recall if word pairs (e.g. ‘lion; meat’) originated from already complete sentences, or from a sentence they completed themselves. Another 10 new word pairs were added that the participant had not read before. In appendix A, an overview of the task is included (in Dutch). In table 1, an overview is given of all possible responses.

Table 1

An overview of possible answers of the Source Recognition Task.

		Response		
		Self	Other	New
True Answer	Self	Self-Hit	Self-Other False Alarm	Self-New False Alarm
	Other	Other-Self False Alarm	Other-Hit	Other-New False Alarm
	New	New-Self False Alarm	New-Other False Alarm	New-Hit

A ‘Hit’ represents a correct attribution to a source. ‘False Alarm’ means an error has been made. The first part of these terms corresponds to the true source, the second part corresponds to the given answer.

Questionnaire for Psychotic Experiences

Next to the Source Recognition Task, the Questionnaire for Psychotic Experiences (QPE) was also administered (Schutte, et al., submitted). This questionnaire consisted of questions about the nature of the hallucinations. Participants were, for example, asked about the frequency, intensity and duration, and start of hallucinations, in the auditory, visual, tactile and olfactory modality. For this study, only the auditory part of the QPE was relevant. Some questions (i.e. A1, A3, A4, A5, A6, A11, A12, A13, A15) were scored on a numeric scale from 0 through 5, and the rest were scored on an alphabetical scale (A-E) with the possibility of multiple answers. See appendix B for an overview of all numerically scored questions. On average, administering the QPE took between 5-10 minutes for NHI. For HHI, it took a very diverse amount of time, depending for instance on the number of modalities on which a participant hallucinated, and the extensiveness of the hallucinations.

A total QPE score was computed to represent the severity of the auditory hallucinations. All items scored on a numerical scale were included in this total score. However, a few difficulties arose trying to compute this variable for all participants, because different versions of the QPE were used. In the version of the QPE used with the first ten participants, questions A6 (impairment of daily functioning) and A15 (presence of auditory illusions) were not included in the questionnaire yet, thus making it impossible to include these questions in the constructed total auditory hallucination measure. Apart from these two questions, question A4 (hallucinations having negative content) was excluded after it was found to have been administered the wrong way, resulting in an exaggeration of the severity of the hallucinations. This resulted in the following information being included in the final total QPE score:

1. The frequency of the hallucinations
2. The duration of the hallucinations
3. The burden of the hallucinations on the participant
4. The insight the participant has into the hallucinations (i.e. to what extent they realize they are not real)
5. To what extent a participant interacts with the hallucinations
6. To what extent a participant obeys the hallucinations

From here on, the term ‘total QPE scores’ refers to the constructed score mentioned above with three excluded questions. For an overview of the original questions in Dutch, together with the excluded questions, see appendix B.

Mini-Mental State Examination

Last, to get an indication of the cognitive capacities of the participant, the Mini-Mental State Examination (MMSE) is administered. This is a short test that screens for cognitive impairment (Folstein, Folstein, & McHugh, 1975; Kok & Verhey, 2002). For the complete MMSE, see appendix C.

Analyses

Analyses were performed using the program IBM SPSS Statistics version 22. First, Mann-Whitney U tests were performed to analyze potential differences in demographics between the groups. Then, to investigate differences in source monitoring abilities, Source Recognition Task performance was compared between HHI and NHI, using multiple Mann-Whitney U tests as well. We expected HHI to perform worse on the Source Recognition Task in general. General Source Recognition Task performance is measured by dividing the number of total Hits by the total number of items, resulting in a Total Hit-rate. More specifically, the HHI group is also expected to make significantly more errors attributing self-generated information to an external source. This has been investigated using the Self-Other False Alarm rate. It could be argued that Self-New False Alarms also represent an externalizing bias, because participants attribute a self-generated word pair to a source outside of themselves. However, the choice was made to leave out this variable, because it was reasoned to represent mostly memory, as this kind of False Alarm only occurs because a participant cannot remember the item at all. False Alarm rates were calculated by taking the number of items falsely attributed to a wrong source (e.g. Self-Other False Alarms) and dividing it by the total number of items in that category (in this case all 'Self' items).

Second, before running the Multiple Regression Analyses, correlations between all predictors had to be checked using Kendall's tau. This way, variables with a correlation higher than .85 could be excluded, because this would indicate that the variables tested concepts too closely related, thus causing multicollinearity in the regression (Schroeder, 1990). After this, the Multiple Regression Analyses were used to investigate if the severity of auditory hallucinations could predict source monitoring abilities. General source monitoring was again represented by the total Hit-rate of the Source Recognition Task. Furthermore, we investigated if the severity of auditory hallucinations could also predict the extent to which an externalizing bias occurs. Thus, another Multiple Regression Analysis was performed trying to predict Self-Other False Alarm rates with hallucination severity.

In these Multiple Regression Analyses, the QPE was the main variable investigated for his effect on the Source Recognition Task outcomes. However, source monitoring could be described as being a cognitive function (Johnson, et al., 1993) so other cognitive functions such as memory and executive functioning were expected to influence Source Recognition Task performance (French, 2006). This is why MMSE total scores were added as a second predictor in these Multiple Regression Analyses, representing general cognitive functioning. Furthermore, Age, Education Level and Gender were also expected to influence outcomes on the Source Recognition Task, which is why these were later also added in each Multiple Regression Analysis.

Results

Sample characteristics

To report the demographical data for both HHI and NHI, a Shapiro-Wilk analysis was performed for the variables Age, Education Level and MMSE total scores. This showed that none of these variables were normally distributed (for Age and MMSE $p<.001$, for Education level $p<.05$), and thus nonparametric tests were used. To analyze potential differences between the groups, Mann-Whitney U tests were performed. As can be seen in table 2, only the MMSE scores differed significantly between the HHI and the NHI ($p=.048$). To analyze the distribution of gender across the two groups, a Pearson Chi-Square was performed, which indicated that no significant difference in gender existed ($p=.511$).

Table 2

Demographic information of HHI and NHI.

Variable	Total	HHI (*n*=56)	NHI (*n*=46)	Statistic	Significance
Age	62.15 (11.83)	61.61 (11.29)	62.80 (12.55)	U = -0.62	p = .536
Education level	5.51 (1.90)	5.25 (1.95)	5.83 (1.82)	U = -1.54	p = .124
Gender m:f	48:54	28:28	20:26	χ^2 = 0.43	p = .511
MMSE total	28.75 (1.73)	28.41 (2.03)	29.15 (1.19)	U = -1.97	p = .048*
Total QPE	4.67 (5.13)	8.50 (3.89)	0.00 (0.00)		

*Significant at the .05 level

Information is presented as *M (SD)*, except gender, which is presented as *n*.

Comparing Source Recognition Task performance

Then, the difference in Source Recognition Task performance was analyzed between the hallucinating group and the non-hallucinating group. Since all measures of the Source Recognition Task violated the assumption of normality, non-parametric Mann-Whitney U tests were performed. As can be seen in table 3, a significant difference was found on the New-Self False Alarm rate between HHI (*M*=.020, *SD*=.041) and NHI (*M*=.000, *SD*=.000). NHI did not make any New-Self False Alarms, while 11 of 56 (20%) of participants in the HHI group made mistakes. Apart from this finding, the two groups did not differ significantly on measures of the

Source Recognition Task (as can be seen in table 3). After performing these tests, a False Discovery Rate (FDR) was used to correct for running multiple Mann-Whitney U tests (Benjamini & Hochberg, 1995). This resulted in a reference *p* value of .005 being used, at which point the New-Self False Alarm rate remains significant.

Table 3

Outcomes of Man-Whitney U tests, analyzing differences in Source Recognition Task outcomes between HHI and NHI

Variable	Total	HHI (n=56)	NHI (n=46)	Statistic	Significance
Self-Hit-rate	.870 (.185)	.861 (.204)	.880 (.160)	*U* = 1203.50	*p* = .548
New-Hit-rate	.931 (.124)	.927 (.143)	.937 (.095)	*U* = 1268.50	*p* = .881
Other-Hit-rate	.334 (.234)	.305 (.235)	.370 (.232)	*U* = 1112.00	*p* = .143
Total Hit-rate	.712 (.114)	.698 (.122)	.729 (.101)	*U* = 1152.50	*p* = .360
Self-Other FA rate	.040 (.072)	.042 (.071)	.037 (.074)	*U* = 1199.50	*p* = .452
Self-New FA rate	.088 (.145)	.093 (.161)	.083 (.125)	*U* = 1268.50	*p* = .885
New-Self FA rate	.011 (.031)	.020 (.041)	.000 (.000)	*U* = 1035.00	*p* = .002*
New-Other FA rate	.052 (.091)	.043 (.087)	.063 (.095)	*U* = 1139.50	*p* = .223
Other-Self FA rate	.091 (.120)	.105 (.130)	.074 (.106)	*U* = 1090.50	*p* = .152
Other-New FA rate	.572 (.235)	.587 (.235)	.554 (.236)	*U* = 1166.50	*p* = .410

*Significant at the .005 level

All scores are presented as *M (SD)*. FA is an abbreviation of False Alarm.

Predicting Source Recognition Task Performance

To see if it was possible to predict outcomes of the Source Recognition Task, Multiple Regression Analyses were performed in the HHI group. Although QPE was the main predictor in these analyses, cognitive functioning was expected to influence the outcomes, and since a significant difference was found between HHI and NHI on MMSE scores, MMSE scores were subsequently added in these Multiple Regression Analyses. However, when assumptions for these analyses were checked, it turned out a number of assumptions were violated. None of the variables used in the regression (i.e. total QPE scores, Total Hit-rate, MMSE scores, Age, Education level) were normally distributed. Furthermore, the residuals of the regression are not homoscedastic. Lastly, using Kendall's tau, several correlations were found between these predictors, although none exceed .85 (as depicted in table 4). This means they do not seem to jeopardize the regression through multicollinearity (Schroeder, 1990). For this correlation analysis no corrections were made for multiple testing. This is because no true conclusions are drawn from this correlation analysis, and there are no consequences of finding any statistical results (Feise, 2002). Furthermore, no corrections were made for the three Multiple Regression Analyses, although this slightly increases the chance of a type I error. Due to the small number of analyses performed, it was not considered necessary to use stricter criteria in interpreting a result as significant (Benjamini, & Hochberg, 1995; Feise, 2002; Van Geloven, 2014).

Table 4

Correlations between predictors and outcome variables using Kendall's Tau

	Age	Education Level	MMSE scores
Total QPE scores	$\tau = -.014^{\dagger}$	$\tau = -.186^{\dagger}$	$\tau = -.029^{\dagger}$
	$p = .881$	$p = .071$	$p = .779$
MMSE scores	$\tau = -.206$	$\tau = .193$	
	$p = .006$*	$p = .018$*	
Education Level	$\tau = -.003$		
	$p = .967$		

* Significant using a reference *p*-value of .05
† Correlations with Total QPE scores were computed using only HHI

Predicting Total Hit-rates

First, a multiple regression was performed trying to predict Total Hit-rates with QPE and MMSE scores. As depicted in table 5, the QPE scores alone are not a significant predictor of Total Hit-rate (p=.382), but MMSE scores are (R^2 =.218, p<.001). Though still significant together (p=.001), adding QPE scores as a predictor only accounts for an additional 0.6% of variance in Total Hit-rates. Subsequently Age, Education Level and Gender were added next to QPE and MMSE scores, to see the additional predictive value of the model. To see how these variables influenced the regression, a Backwards Multiple Regression was used. This way, it was possible to look what variables had the most influence on the model and thus influence the formation of the model. However, adding these three variables only accounted for an additional 2.1% of variance in Total Hit-rates (R^2 =.246, F= 3.24, p=.013). Respectively, MMSE, Education Level and Age were the three best predictors.

Table 5

Different models predicting Total Hit-rates

Model	Beta	R square	Statistic	Significance
QPE	-.119	.014	F = 0.78	p = .382
MMSE	.467	.218	F = 15.01	p = .000**
QPE+MMSE		.224	F = 7.67	p = .001*

* Significant at the .001 level
‘QPE’ represents total QPE scores, ‘MMSE’ represents MMSE total scores

Predicting Self-Other False Alarm rates

Next, a Multiple Regression Analysis was performed with Self-Other False Alarm rates as an outcome variable and QPE and MMSE scores as predictors. As can be seen in table 6, the predictive value of QPE alone was not significant, although a trend could be observed (p = .063). Then, the MMSE was added, and it turned out together they account for 11% of variance (p = .046). Another regression was then performed to check if the MMSE scores alone would have been able to significantly predict Self-Other False Alarm rates, but this was not the case (p = .077). Then, a Backwards Regression Analysis was again used to see if the ability to predict Self-Other False Alarm rates would be improved if more variables were used. Thus, besides the total

QPE scores and the MMSE scores, Age, Education level and Gender were added as well. However, adding these variables resulted in a no longer significant model predicting the Self-Other False Alarm rates (R^2 =.137, F=1.59, p=.179).

Table 6

Different models predicting Self-Other False Alarm rates

Model	Beta	R square	Statistic	Significance
QPE	.250	.057	F = 3.60	p = .063
MMSE	.057	.062	F = 3.26	p = .077
QPE+MMSE		.110	F = 3.26	p = .046*

* = significant at the .05 level
'QPE' represents total QPE scores, 'MMSE' represents total MMSE scores

Predicting New-Self False Alarm rates

Finally, a last Multiple Regression Analysis was performed to try to explain the unexpected difference found in New-Self False Alarm rates between HHI and NHI. Again, QPE and MMSE scores were used as predictors. As can be seen in table 7, using only QPE scores had almost no predictive value (p=.765), but a trend can be seen using only MMSE scores (p=.081. When both predictors are used, the model becomes even less significant than when only MMSE is used (p=.198).

Table 7

Different models predicting New-Self False Alarm rates

Model	Beta	R square	Statistic	Significance
QPE	-.041	.002	F = .09	p = .765
MMSE	-.236	.055	F = 3.17	p = .081
QPE+MMSE		.059	F = 1.67	p = .198

'QPE' represents total QPE scores, 'MMSE' represents total MMSE scores

However, when again a Backwards Multiple Regression Analysis is performed using Age, Education Level and Gender as predictors as well, it turns out that New-Self False Alarm rates can be significantly predicted by these variables. It shows that, respectively, Age, MMSE and Education Level are the best predictors of New-Self False Alarm rates. MMSE and Age together account for 14% of variance (F=4.32, *p*=.018), while MMSE, Age and Education Level together account for 14.8% of variance in New-Self False Alarm rates (*F*=3.01, *p*=.038).

Discussion

To summarize, this study was comprised of two research questions. In the first part, we investigated differences in source monitoring abilities between hearing impaired individuals with, and those without auditory hallucinations, as measured by different kinds of Source Recognition Task performance. In the second part, Multiple Regression Analyses were used to see if the severity of auditory hallucinations could predict general Source Recognition Task performance, Self-Other False Alarm rates, and New-Self False Alarm rates.

Comparing Source Recognition Task performance

First, multiple Mann-Whitney U tests were performed to examine the differences on the Source Recognition Task between HHI and NHI. In previous research, a decrease in general source monitoring abilities had been found in hallucinating schizophrenia patients (Anselmetti, et al., 2005; Brébion, Gorman, Amador, Malaspina, & Sharif, 2002; Keefe, Arnold, Bayen, McEvoy, & Wilson, 2002; Stephane, Kuskowski, McClannahan, Surerus, & Nelson, 2010). The same finding was expected in the hearing impaired patients of this study, meaning a significantly lower Total Hit-rate in HHI than in NHI. However, no such difference could be found. Furthermore, a larger externalizing bias was expected in HHI than in NHI, meaning a significantly higher Self-Other False Alarm rate (Brébion, et al., 2000; Fisher, McCoy, Poole, & Vinogradov, 2008). Again, no statistically significant difference could be found. This indicates that experiencing hallucinations does not have an influence on source monitoring in general, or the degree to which the externalizing bias can be found. In schizophrenia, ambiguous results have been be found comparing schizophrenia patients with hallucinations and those without (Seal, et al., 1997; Brunelin, et al., 2006). However, the main theory about the origins of auditory hallucinations in schizophrenia is that they are caused by an externalizing bias. The lack of a difference in source monitoring between HHI and NHI in this study seems to indicate that source monitoring does not play a major role in the origin of hallucinations in hearing impairment. This could signify that different mechanisms underlie hallucinations in schizophrenia and hearing impairment.

A second finding in comparing Source Recognition Task performance between HHI and NHI was an unexpected difference in New-Self False Alarm rates. This translates to a tendency of hallucinating participants to attribute new information to themselves, which seems to be the opposite of the externalizing bias we were expecting to find. Seeing as MMSE scores differed between HHI and NHI, cognitive functioning may play a role in this finding (further explored later).

Predicting Source Recognition Task outcomes

Next, we attempted to predict several Source Recognition Task outcomes using total QPE scores and MMSE scores as main predictors. These represent the severity of hallucinations and cognitive functioning.

Predicting Total Hit-rates

First, a Multiple Regression Analysis was used to predict Total Hit-rates in HHI by using QPE and MMSE scores. Since MMSE was shown to differ between HHI and NHI, and because cognition is known to influence source monitoring, MMSE scores were added as a predictor in the analyses. Results show that QPE alone is not a good predictor, but adding MMSE, and even MMSE by itself, is a strong predictor of Total Hit-rates (French, 2006). Additionally, MMSE, Education Level and Age are the three best predictors of Total Hit-rates. Since these three variables are all indicative of a participant's cognitive capacity, this means that cognition is the most important determinant of total Hit-rates. The general ability with which participants distinguish the source of certain pieces of information does not seem dependent on the presence of auditory hallucinations, or the severity of those hallucinations. This corresponds to a finding in the schizophrenia population. Seal, et al. (1997) found that any differences in source monitoring abilities between patients with hallucinations, compared to those without hallucinations, disappeared when controlling for verbal memory and verbal intelligence.

Predicting Self-Other False Alarm rates

Next, we attempted to predict the extent of the externalizing bias of the HHI group based on the severity of auditory hallucinations. This measure includes frequency, duration, and the burden of the hallucinations, the insight participants have into the hallucinations, interaction they have with the hallucinations, and if they obey their hallucinations (see appendix B). The externalizing bias was represented by the Self-Other False Alarm rate. As it turns out, the QPE alone cannot accurately predict Self-Other False Alarm rates, although a trend can certainly be observed. When combined with total MMSE scores though, these variables together can significantly predict Self-Other False Alarm rates.

Here, a discrepancy seems to exist. Even though no difference in Self-Other False Alarm rates was found between HHI and NHI, an association was found between the intensity of hallucinations and Self-Other False alarm rates. It might suggest that experiencing hallucinations by itself is not indicative of an externalizing bias, but when a person hallucinates, externalizing bias increases when hallucinations are more severe. As also shown in the previous paragraph, the addition of MMSE scores in this model suggests an influence of cognition on source monitoring abilities. However, adding the cognitive components of Age and Education level resulted in the model being no longer significant. This indicates that cognition plays a less prominent role in predicting Self-Other False Alarm rates, yet especially the interaction between cognition and severity of hallucinations is indicative of a participant's tendency to make externalizing errors.

Predicting New-Self False Alarm rates

As a significant difference was found in New-Self False Alarm rates between HHI and NHI, we also performed a Multiple Regression Analysis with this variable, in order to see if we can find out more about the factors predicting these scores. This analysis shows that neither MMSE or QPE, nor both, can significantly predict New-Self False Alarm rates. However, another Regression shows that when using MMSE and Age, or MMSE, Age and Education level together, the model does become significant. Together with the finding that MMSE scores differed significantly between HHI and NHI, this again suggests that the extent to which a person attributes new information to themselves, can for a great part be explained by cognition. It seems to have no direct relation with the severity of someone's hallucinations.

Taking the results of these Multiple Regression Analyses together, cognition (represented by MMSE, Age and Education Level) seems to play a central role in all measures of the Source Recognition Task. This suggests that source monitoring in general is mostly influenced by cognition, which makes sense since source monitoring is sometimes even described as being a cognitive function itself (Johnson, et al., 1993). It is expected that the better a participant's cognitive functioning, the better they can remember the source of certain information. Similar results in schizophrenia have been found by Seal et al. (2010), who found that any differences in general source monitoring between hallucinating and non-hallucinating schizophrenia patients could be explained by verbal IQ and verbal memory. In contrast, severity of hallucinations does not seem to influence general source monitoring performance. However, in Self-Other False Alarm rates, severity of hallucinations does play a role. This suggests that instead of deficits in general source monitoring, only the externalizing bias is associated with auditory hallucinations in hearing impairment. This again corresponds to a study comparing hallucinating schizophrenia patients with healthy subjects without schizophrenia. Here, they found no differences in general source monitoring abilities, but instead only found a difference in the extent to which an externalizing bias could be found (Stephane, Kuskowski, McClannahan, Surerus, & Nelson, 2010).

Combining these findings with the first part of the results, it indicates that in this sample, the presence of an externalizing bias is not indicative of the presence of auditory hallucinations. Therefore, the externalizing bias might not play a role in the origins of auditory hallucinations in hearing impairment after all. The fact that this is one of the main theories about the origins of auditory hallucinations in schizophrenia, may indicate that different mechanisms underlie auditory hallucinations in these disorders. However, since an association was found between the degree of externalizing bias and the severity of hallucinations, this seems to suggest that the externalizing bias is somehow connected to auditory hallucinations in hearing impairment too.

Strengths and Limitations

This study had a number of strengths. First, this study is the first that explores the role of source monitoring in hallucinations in hearing impairment. It investigates not only general source monitoring in these individuals, but also more specifically investigates the externalizing bias. Second, the sample size is large enough to provide sufficient power to give its findings a certain weight. Third, a large part of the study layout was standardized, meaning the QPE, SRT and MMSE were all standardized measures, being administered the same way for all participants. All researchers in the UH study were trained in administering all tests, so interrater reliability is expected to be high. In turn, this results in reliable results across participants. The reliability of the data is further enhanced by the fact that participants' original QPE data was manually checked in order to exclude scores on the three questions mentioned before, while simultaneously checking all participants for possible exclusions. Another strength of the study lies in the Source Recognition Task. It is long enough to provide sufficient information of their source monitoring abilities, but short enough to make sure the participant does not get tired or becomes eager to finish (Vinogradov, et al., 1997). Additionally, since the Source Recognition Task is read aloud by participants, and hallucinations in this group are auditory, it appears the task measures what it intends to measure, although no official data exists on its validity. Throughout literature, paradigms have been used and discussed (although not in the hearing impaired population) that are variations of or similar to the Source Recognition Task used in this study (Fisher, et al., 2008; Mitchel, & Hunt, 1989; Mitchell, Hunt, & Schmitt, 1986).

However, there are also a few limitations of the study, that could contribute to the limited amount of results found. The first major limitation contains the three questions of the QPE that had to be excluded in order to compute a measure of the severity of the auditory hallucinations. The first question was about the negativity of the content of the auditory hallucinations (e.g. hearing insults or swearing). This question was excluded because, even though administration of the QPE was standardized, for multiple participants this question was scored with the maximum score of 5, while the participant only heard non-verbal auditory hallucinations. We then found out that this question had been interpreted to mean 'to what extent a participant finds the hallucinations a ‘negative’ influence on their life’. This of course decreased the validity of this question, and if included, would have in turn decreased the validity of the total QPE scores. However, removing this question was not expected to have much impact on the validity of the total QPE measure, due to its very small variance if it would have been scored correctly. Ten participants were found to experience only nonverbal hallucinations. Since nonverbal hallucinations cannot have negative content, the true scores of these other participants would be zero if scored correctly, leaving only six participants scoring above zero. Two more questions were subsequently excluded because they were not yet present in the earliest version of the QPE. One question that was thus excluded measured the extent to which a person’s daily functioning is impaired because of the auditory hallucinations. This question was especially expected to contribute to the total score, since it represented the inconvenience or trouble that the hallucinations cause, and would thus be a good question to add to a measure of severity of hallucinations. The last excluded question was about the frequency of auditory illusions, on which most participants scored 0 or 1 point, and was therefore not a major contributor to the total score. Because of these omitted questions, the current total auditory hallucination score may have slightly less variance than it originally would have. However, excluding the 10 participants without scores on the second and third question would have resulted in a selection bias, because they all experienced auditory hallucinations. A second limitation of this study is the fact that the Source Recognition Task suffers from a ceiling effect. To illustrate, of 56 HHI, 38 did not make any Self-Other False Alarms (68%). This small variance in scores decreases the predictive effect of hallucination severity of these scores. A last limitation presented itself in the results section. Even though several assumptions of the Multiple Regression Analyses were offended, there were no other ways of testing the second research question. None of the variables used were normally distributed, statistically significant correlations were found between predictors, and the residuals of the Regressions were not always normally distributed, linear and homoscedastic. Although a Multiple Regression Analysis is quite robust against violations of the assumptions, it could decrease any effects found. This also means that conclusions drawn, based on these analyses, must be interpreted with caution.

Future Research

As mentioned before, this study seems to be the first to look at source monitoring in hearing impaired patients that experience hallucinations. Although no externalizing bias could be found in HHI compared to NHI, this does not mean that none exists, especially since a relation was found between severity of hallucinations and an externalizing bias within HHI.

Further research replicating these results is necessary to make more definitive statements about source monitoring in the hearing impaired population with hallucinations. Also, it would be interesting to compare Source Recognition Task performance of hearing impaired patients with schizophrenic patients, to see if differences can be found. This could then provide further evidence of different mechanisms underlying these two disorders. In that same line, perhaps phenomenological properties of the hallucinations may be compared between hearing impaired patients, and patients with schizophrenia. There could be differences in, for example, the extent to which the hallucinations are verbal, or the extent to which hallucinations are interpreted as being negative. If such differences could be found, this may in part explain the lack of findings in this study, compared to previous studies finding differences between patients with schizophrenia with and without hallucinations.

Next to hearing impairment and schizophrenia, other populations are also known to hallucinate. It would be interesting to study source monitoring in these populations as well. In visually impaired individuals for example, complex visual hallucinations can occur (Menon, Rahman, Menon, & Dutton, 2003; Kester, 2009). However, using different populations could present complications administering the Source Recognition Task. Since this task is read from a piece of paper, this could limit the ability to administer this in the visually impaired group. To solve this, it could be interesting to use a different kind of test to measure source monitoring. For example non-verbal, action-based source monitoring paradigms (Danion, Rizzo, & Bruant, 1999; Humpston, Linden & Evans, 2017) have been used before. Such a non-verbal measure could provide valuable insight into different kinds of source monitoring, even disregarding its increased value for visually impaired participants.

The same counts for picture-based tasks (Brébion, et al., 2000). Not all auditory hallucinations are verbal in nature, and it would be interesting to look across populations if different results might be found if a different paradigm is used.

Conclusion

Although no difference could be found in source monitoring between hallucinating hearing impaired individuals and non-hallucinating hearing impaired individuals, experiencing more severe hallucinations has been associated with a larger externalizing bias. The externalizing bias was the only measure of source monitoring not merely explained by cognition, but also by severity of hallucinations. Since the presence of hallucinations does not seem indicative of an externalizing bias, the reverse could also be the case. Therefore, if an externalizing bias does not play a role in the origins of auditory hallucinations in hearing impairment, this could indicate that different mechanisms underlie auditory hallucinations in hearing impaired patients, compared to schizophrenia patients.

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Appendix

Appendix A: The Source Recognition Task

Versie A:

1. De ridder versloeg de draak.

2. De geit at de __________.

3. De president tekende de rekening.

4. Het paard rent in de __________.

5. De dokter genas de patiënt.

6. De eigenaar kocht de__________.

7. De matroos zeilde het schip.

8. De boer ploegde het __________.

9. De leeuw at het vlees.

10. De makelaar verkocht het __________.

11. De koningin heerste over het land.

12. De tijger at de __________.

13. De leraar gaf de toets.

14. De oom hield van de __________.

15. De spin maakte het web.

16. De duivel verleidde de __________.

17. De wolf at het konijn.

18. De kunstenaar schilderde het __________.

19. De gast at de maaltijd.

20. De vader sloeg het __________.

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Source Memory

		Zelf	Ander	Nieuw
kameel	…………			
dokter	…………			
tijger	…………			
ridder	…………			
piloot	…………			
reptiel	…………			
spin	…………			
president	…………			
eigenaar	…………			
publiek	…………			
zebra	…………			
duivel	…………			
paard	…………			
makelaar	…………			
gids	…………			
matroos	…………			
boer	…………			
tovenaar	…………			
leraar	…………			
team	…………			
wolf	…………			
leeuw	…………			
kunstenaar	…………			
oom	…………			
astronaut	…………			
vader	…………			
geit	…………			
koningin	…………			
gast	…………			
gokker	…………			

Appendix B: List of QPE questions scored numerically

Note: Questions in red were later excluded due to differing versions of the QPE (A6 and A15) or due to researchers administering the question wrong (A4).

A1 a. Het komt weleens voor dat men iemand hoort spreken, terwijl er niemand lijkt te zijn. Ook kunnen geluiden of muziek worden gehoord, terwijl het niet duidelijk is waar dat vandaan komt. Heeft u weleens zulke stemmen, muziek of andere geluiden gehoord?

b. Zo ja, heeft u dit in de afgelopen week nog ervaren?
0: Minder dan een keer per maand
1: Minimaal eens per maand
2: Minimaal eens per week
3: Minimaal eens per dag
4: Minimaal eens per uur
5: (Bijna) altijd

A3 Wanneer u de (vul auditieve hallucinatie in) **in de afgelopen week hoorde, hoe lang duurde dit toen?**
0: Heel kort; slechts een ogenblik
1: Een paar seconden
2: Een minuut of hooguit enkele minuten
3: 10 minuten tot een uur
4: Een uur tot enkele uren
5: (Bijna) altijd

A4: Sommige mensen horen stemmen of geluiden met een negatieve inhoud, waaronder kritiek en vijandigheid. Welk deel van de stemmen en/of geluiden heeft u in de afgelopen week als negatief ervaren?
0: Nooit negatief, de hele inhoud is positief, nuttig of neutraal
1: Af en toe negatieve inhoud, maar dit is zelden het geval (<10%)
2: Een gedeelte van de inhoud is negatief
3: Ongeveer de helft van de inhoud is negatief
4: De meerderheid van de inhoud is negatief
5: Altijd, de hele inhoud is negatief

A5 Heeft in de afgelopen week u weleens last van de (vul auditieve hallucinatie in) **gehad?**
0: Geen ongemak, het beïnvloedt de deelnemer niet
1: Twijfel, misschien een beetje ongemakkelijk
2: Een beetje ongemakkelijk, de stemming of het gedrag kan worden beïnvloed
3: Aanzienlijk ongemak, het veroorzaakt soms een angstig, onrustig of depressief gevoel
4: Heel veel last, het veroorzaakt vaak een angstig, onveilig of depressief gevoel
5: Intense last, de stemmen of geluiden veroorzaken een ernstige depressie of angst

A6 Beïnvloeden de geluiden uw dagelijks functioneren?
0: Ze hebben geen effect op het uitvoeren van normale dagelijkse activiteiten
1: Ze beperken bij een aantal specifieke activiteiten, maar de meeste dingen kunnen worden uitgevoerd
2: Ze zijn beperkend bij diverse activiteiten

3: Ze weerhouden van de meeste activiteiten (bijvoorbeeld het huis niet verlaten)
4: Ze zijn zo verstorend dat het aanzet kan geven tot schelden, schreeuwen of vernieling
5: Ze veroorzaken verstoring van het dagelijks functioneren. Ziekenhuisopname of crisisopvang is mogelijk nodig

A11 Mensen denken verschillend over de oorzaak van de geluiden die ze horen. Sommige mensen zeggen dat ze mensen/wezens/geluiden horen die echt bestaan. Andere mensen zeggen dat de geluiden worden gecreëerd door de eigen hersenen. Wat denkt u dat maakt dat u (vul auditieve hallucinatie in) **hoort?**
0: Volledig van overtuigd dat de stemmen, geluiden of muziek **niet** echt zijn
1: Lichte twijfel of ze echt zijn, waarschijnlijk niet echt
2: Ze zijn waarschijnlijk echt, maar alternatieve verklaringen zijn ook mogelijk
3: Sterk overtuigd dat ze echt zijn, slechts minimale twijfel
4: Volledige overtuiging dat ze echt zijn

A12 Sommige mensen merken dat ze reageren op de stemmen of andere geluiden. Dat kan hardop of in gedachten. In de afgelopen week, hoe vaak heb je gemerkt dat je reageert op de stemmen of geluiden? Wanneer u de (vul auditieve hallucinatie in) **hoort, praat u dan weleens terug?**
0: Nooit enige interactie gehad
1: Eén of enkele keren
2: Alleen wanneer de stemmen heftig zijn, normaal gesproken niet
3: Soms, maar niet altijd
4: Meerderheid van de tijd
5: (Bijna) altijd

A13 Geven de stemmen u weleens opdrachten? Zo ja, voert u de opdrachten ook uit?
0: Krijgt nooit opdrachten
1: Krijgt wel opdrachten, maar voert ze nooit uit
2: Voert soms onschuldige opdrachten uit (bijvoorbeeld tanden poetsen)
3: Voert altijd onschuldige opdrachten uit, maar geen gevaarlijke
4: Voert soms gevaarlijke opdrachten uit (bijvoorbeeld van de trap af springen)
5: Voert alle opdrachten altijd uit, ook de gevaarlijke

A15 Sommige mensen horen weleens de telefoon gaan, terwijl ze onder de douche staan. Als ze de douche uitzetten blijkt dit geluid er niet te zijn. Een ander voorbeeld is dat iemand een stem denkt te horen in het zoemen van de stofzuiger. Heeft u zoiets weleens ervaren?
0: Nooit tot minder dan eens per maand
1: Minimaal eens per maand
2: Minimaal eens per week
3: Minimaal eens per dag
4: Minimaal eens per uur
5: (Bijna) altijd

Appendix C: The Mini-Mental State Examination

Gestandaardiseerde MMSE

Naam patiënt :

Datum invullen : Naam invuller :

Ik ga u nu enkele vragen stellen en geef u enkele problemen om op te lossen. Wilt u alstublieft uw best doen om zo goed mogelijke antwoorden te geven.

noteer antwoord score:

1. a. Welk jaar is het?
   b. Welk seizoen is het?
   c. Welke maand van het jaar is het?
   d. Wat is de datum vandaag?
   e. Welke dag van de week is het?
   (0-5) ________

2. a. In welke provincie zijn we nu?
   b. In welke plaats zijn we nu?
   c. In welk ziekenhuis (instelling) zijn we nu?
   d. Wat is de naam van deze afdeling?
   e. Op welke verdieping zijn we nu? (0-5) ________

3. Ik noem nu drie voorwerpen. Wilt u die herhalen nadat ik ze alle drie gezegd heb?
   Onthoud ze want ik vraag u over enkele minuten ze opnieuw te noemen.
   (Noem "appel, sleutel, tafel", neem 1 seconde per woord)
   (1 punt voor elk goed antwoord, herhaal maximaal 5 keer
   tot de patiënt de drie woorden weet) (0-3) ________

4. Wilt u van de 100 zeven aftrekken en van wat overblijft weer zeven aftrekken
   en zo doorgaan tot ik stop zeg?
   (Herhaal eventueel 3 maal als de persoon stopt, herhaal dezelfde instructie,
   geef maximaal 1 minuut de tijd) Noteer hier het antwoord.

of

   Wilt u het woord "worst" achterstevoren spellen?.
   Noteer hier het antwoord.
   (0-5) ________

5. Noemt u nogmaals de drie voorwerpen van zojuist.
   (Eén punt voor elk goed antwoord). (0-3) ________

6. Wat is dit? En wat is dat?
   (Wijs een pen en een horloge aan. Eén punt voor elk goed antwoord). (0-2) ________

7. Wilt u de volgende zin herhalen: " Nu eens dit en dan weer dat ".
   (Eén punt als de complete zin goed is) (0-1) ________

8. Wilt u deze woorden lezen en dan doen wat er staat?
   (papier met daarop in grote letters: "Sluit uw ogen") (0-1) ________

9. Wilt u dit papiertje pakken met uw rechterhand, het dubbelvouwen
   en het op uw schoot leggen? (Eén punt voor iedere goede handeling). (0-3) ________

10. Wilt u voor mij een volledige zin opschrijven op dit stuk papier?
    (Eén punt wanneer de zin een onderwerp en een gezegde heeft
    en betekenis heeft). (0-1) ________

11. Wilt u deze figuur natekenen?
    (Figuur achterop dit papier. Eén punt als figuur geheel correct is nagetekend.
    Er moet een vierhoek te zien zijn tussen de twee vijfhoeken) (0-1) ________

TOTALE TEST SCORE: (0-30) ________

Sluit uw ogen