

Somatosensory Tinnitus Diagnosis: Diagnostic Value of Existing Criteria

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## 1 Abstract

2 **Background:** Tinnitus can be influenced by changes in somatosensory afference from the cervical spine  
3 or temporomandibular area, then called somatosensory or somatic tinnitus (ST). In 2018, a new set of  
4 diagnostic criteria for ST was agreed upon by a large group of ST experts. Currently, however, it still  
5 requires extensive and specific expertise to diagnose ST correctly. The next step in the development  
6 of easily applicable diagnostic criteria is to assess the diagnostic value of each individual criterion.

7 **Objectives:** The aim of this study was therefore, to further investigate the diagnostic value of these  
8 criteria, validate them empirically and identify their sensitivity and specificity.

9 **Methods:** An online survey, questioning the presence of 12 diagnostic criteria for ST in a convenience  
10 sample of participants with tinnitus, was launched on the online forum Tinnitus Talk, managed by  
11 Tinnitus Hub. Participants were divided into three groups: a group with no somatic influence, a group  
12 with some somatic influence and a group with large somatic influence on their tinnitus. Chi-square  
13 tests were used to calculate differences between these groups. Afterwards, sensitivity, specificity,  
14 positive and negative likelihood ratio's (LR) and pre- and post-test probabilities were calculated for  
15 each ST diagnostic criterion. For this analysis, all patients with some and large somatic influence were  
16 compared as one group to the group with no somatic influence.

17 **Results:** In total, 8221 participants filled out the online survey. As expected, the diagnostic criteria for  
18 ST are more prevalent in the groups with somatic influence, but the criterium of tinnitus modulation  
19 also often occurs in the group with no somatic influence. The simultaneous onset or increase and  
20 decrease of both tinnitus and pain complaints have the highest positive LR (6.29 and 10.72  
21 respectively), next to the influence of certain postures on the tinnitus (+LR: 6.04). To rule out ST, the  
22 absence of neck pain or tension in the neck extensor muscles are most suited, as they decrease the  
23 post-test probability to 18 and 19% respectively.

24 **Conclusion:** The simultaneous onset or increase and decrease of tinnitus and neck or jaw pain and the  
25 influence of certain postures are most suited to use as a single criterion for identifying patients with a

26 somatic influence on their tinnitus. On the other hand, the absence of neck pain or tension in the neck  
27 extensor muscles are valid criteria to rule out a somatic influence. Additional analysis is needed to  
28 identify clusters of symptoms and criteria to further aid ST diagnosis.

29 **Keywords:** Tinnitus, somatic, somatosensory, diagnosis

30

31 Introduction

32 Tinnitus, the perception of sound in the absence of overt acoustic stimulation, occurs in 10 to 15% of  
33 adults (Baguley et al. 2013). Typically, tinnitus is related to hearing loss or a noise trauma, where  
34 cochlear abnormalities are the initial source, and neural changes in the central auditory system  
35 maintain the tinnitus (Baguley et al. 2013). Since the 1990s, scientists have described the possible  
36 influence of somatosensory input from the cervical spine and temporomandibular area on tinnitus  
37 complaints (Hiller et al. 1997; Pinchoff et al. 1998). In 1999, Levine first published a hypothesis for this  
38 tinnitus subtype which he called somatic tinnitus (ST) (Levine 1999). Since then, researchers have  
39 found brainstem connections between the somatosensory system and the auditory system in both  
40 animal models and human studies (Lanting et al. 2010; S. E. Shore 2011; Zhan X 2006). These studies  
41 showed that cervical and temporomandibular somatosensory information is conveyed to the brain by  
42 afferent fibres, the cell bodies of which are located in the dorsal root ganglia or the trigeminal ganglion.  
43 Some of these fibres also project to the central auditory system. This enables the somatosensory  
44 system to influence the auditory system by altering spontaneous firing rates or synchrony of firing  
45 among neurons in the cochlear nucleus, inferior colliculus or auditory cortex. In this way, the  
46 somatosensory system may cause tinnitus and/or alter the pitch or loudness of an existing tinnitus (S.  
47 Shore et al. 2007).

48 In those early days, ST was described as a subtype of tinnitus. Through the years and with evolving  
49 knowledge however, the idea of the existence of different tinnitus subtypes, based on their aetiology,  
50 is increasingly being abandoned. Nowadays, tinnitus experts agree that in most patients, tinnitus has  
51 a multifactorial origin with a multitude of potential influencing factors (Cederroth et al. 2019; S.  
52 Michiels et al. 2018; Van de Heyning et al. 2015). In the light of this evolution, ST can be defined as a  
53 tinnitus that is influenced by the cervical or temporomandibular somatosensory system. In 2018, a  
54 group of 15 international experts in ST (83% of the identified experts worldwide) agreed on a new set  
55 of 16 diagnostic criteria for ST, after a Delphi study with consensus meeting (S. Michiels et al. 2018).  
56 An overview of the 16 criteria can be found in supplement 1. The presence of each one of these criteria

57 strongly suggests a somatic influence of a patient's tinnitus, but the experts agreed that the presence  
58 of just one criterion is not enough for a ST diagnosis. Additionally, they agreed that the criteria on  
59 tinnitus modulation should be used carefully, because the ability to modulate the tinnitus alone is not  
60 strong enough for a clear ST diagnosis. Furthermore, in some patients, the presence of another clear  
61 influence, such as for instance an anxiety disorder or a recent noise trauma, adds to the diagnosis. It  
62 therefore still requires a lot of expertise and experience with tinnitus in general to make a good ST  
63 diagnosis, without the risk of under- or overdiagnosis.

64 Therefore, this study aims to investigate the prevalence of each one of the diagnostic criteria for ST in  
65 a large group of people with tinnitus (ST and non-ST) and to further investigate the diagnostic value of  
66 these criteria, validate them empirically and identify their sensitivity and specificity. This will enable us  
67 to evaluate the diagnostic value of each criterion, to aid ST diagnosis and further develop the diagnostic  
68 criterion of somatic tinnitus.

## 69 Methods

### 70 Survey

71 An online survey, in a convenience sample of participants with tinnitus, was launched on the online  
72 forum Tinnitus Talk, managed by Tinnitus Hub, in September 2019. This survey included questions on  
73 the presence of the diagnostic criteria for ST, together with a set of questions on other potential  
74 influencing factors. The questions were designed by the first (SM) and last author (WS) and consisted  
75 of 12 of the 16 diagnostic criteria for ST and a set of complementary questions about the tinnitus and  
76 potential co-morbidities. The four remaining diagnostic criteria could not be used in the survey,  
77 because they involve physical testing, which cannot be assessed via an online questionnaire. The  
78 survey was trailed with a small pool of the forum's community prior to launch. This was done to make  
79 sure that all questions were clear and unambiguous and that no technical issues were present. The  
80 final questionnaire consisted of 42 questions and is displayed in supplement 2.

81 The survey was advertised on the Tinnitus Talk forum, the Tinnitus Hub newsletter and their social  
82 media accounts. It was launched as an open survey, open to everyone who received the survey link. IP  
83 check was used to identify and block potential duplicate entries from the same user. All participants  
84 gave informed consent to use their anonymized data. No personal information was collected during  
85 the process.

86 Ethical approval was obtained from the ethics committee of the Antwerp University Hospital (Ref.  
87 19/43/485). All participants gave their written informed consent to use their anonymized data before  
88 completing the survey.

#### 89 Data analysis

90 First, general characteristics such as average age and gender distribution were calculated. Afterwards,  
91 participants were divided into three groups: no somatic influence, some somatic influence and large  
92 somatic influence. The groups were defined based on the reported diagnosis according to the physician  
93 (question 6: What does your doctor believe is the main cause of your tinnitus?) and a question on  
94 experienced influence from cervical spine and temporomandibular problems (question 23: Have you,  
95 in the past 4 weeks, experienced an influence of neck or jaw problems on your tinnitus?). Patients  
96 were categorized as 'high somatic influence' when their physician indicated a somatic origin of the  
97 tinnitus and the patient answered 'yes, every day' or 'yes, most of the days' to question 23. Patients  
98 were categorized as 'some somatic influence' when they indicated 'yes, every day' or 'yes, most of the  
99 days' to question 23, but their physician did not indicate a somatic origin of the tinnitus. Patients were  
100 additionally categorized as 'some somatic influence' in case their physician did indicate a somatic origin  
101 of the tinnitus and the patient answered 'yes, some days' on question 23. All other patients were  
102 categorized as 'no somatic influence'.

103 Differences in the answers to the different questions between the three groups were analysed using  
104 Chi-square tests. Correction for multiple comparison was made with the Benjamini-Hochberg false

105 discovery rate procedure, using a false discovery rate of 5%. In the Results section, only the corrected  
106 Benjamini-Hochberg P values are presented. The significance level was set at P less than .05.

107 Additionally, the sensitivity, specificity, positive and negative likelihood ratios and pre- and post-test  
108 probability were calculated for each of the diagnostic criteria for ST that were questioned. For this  
109 analysis, the groups with some and large somatic influence were combined into one group to compare  
110 them to the group with no somatic influence. For each criterion a two-by-two table containing the  
111 number of true and false positives and negatives was created. Based on these tables, the sensitivity  
112 was calculated by dividing the number of true positives by the sum of the number of true positives and  
113 false negatives. The specificity was calculated by dividing the number of true negatives by the sum of  
114 the number of true negatives and false positives. The positive likelihood ratio was calculated as the  
115 sensitivity divided by 1 minus the specificity. The negative likelihood ratio was calculated as 1 minus  
116 the sensitivity divided by the specificity. The pre-test probability was calculated as the sum of the  
117 number of true positives and false negatives, divided by the total number of patients included in the  
118 study. The negative post-test probability was calculated as the number of false negatives divided by  
119 the sum of the number of false negatives and true negatives. And finally, the positive post-test  
120 probability was calculated as the number of true positives divided by the sum of the number of true  
121 positives and false positives).

122 Only complete questionnaires, without missing data, were used for the analysis. All analyses were  
123 performed using IBM SPSS Statistics for Macintosh (version 26.0; IBM Corporation).

## 124 Results

125 In total, 8221 participants, averagely aged 50.73 years old (SD: 16.78), filled out the online survey  
126 completely. In the results below, we will first describe the general characteristics of the sample,  
127 comparing the three subgroups: no somatic influence, some somatic influence and large somatic  
128 influence. Afterwards the presence of the 12 diagnostic criteria for ST will be compared. Finally, the  
129 diagnostic value of each one of the 12 diagnostic criteria for ST will be presented.

130 General characteristics

131 Of the total sample of 8221 participants, 73.7% (n=6056) showed no somatic influence, 25.2% (n=2072)  
132 showed some influence of the somatic system and 1.1% (n= 93) had a large somatic influence on their  
133 tinnitus. Details on the described characteristics can be found in table 1.

134 No significant differences in age were found between the different groups, but there was a significant  
135 difference in gender distribution. In the group of patients with no somatic influence, there was a higher  
136 percentage of men than women, while in the groups with somatic influence, percentages of males and  
137 females are more evenly distributed with higher percentages of females the higher the somatic  
138 influence (Figure 1). Tinnitus severity and loudness differed significantly across the three groups.  
139 Tinnitus severity was described as moderate to severe in the majority of participants in all three  
140 groups, but the group with large somatic influence showed more variety in tinnitus severity. Whereas  
141 in the groups with no and some somatic influence, the tinnitus severity is rated as moderate in about  
142 45%, only 36.6% rates his/her tinnitus severity as moderate in the high somatic influence group. The  
143 remaining participants in this group rated their tinnitus severity more to the extremes (borderline or  
144 catastrophic). The tinnitus loudness, on the other hand, shows an increase across the groups with the  
145 loudest tinnitus in those patients with the highest somatic influence.

146 PLEASE INSERT FIGURE 1

147

148 The tinnitus sound also differed significantly between the three groups, with a tendency to have more  
149 'mixture of tones' and 'pulsating tinnitus' in the groups with higher somatic influence. Hissing and pure  
150 tone tinnitus, on the other hand, seem to be more prevalent in the group with no somatic influence.

151 The presence of hyperacusis interestingly also increases with the degree of somatic influence. Whereas  
152 45% of participants in the no somatic influence group indicates to have no hyperacusis, this percentage  
153 gradually decreases to 30.1% in the group with high somatic influence (figure 2). The other way around,

154 hearing loss seems to be more typical for tinnitus with no somatic influence (55.3%) compared to some  
155 somatic influence (52.7%) and large somatic influence (45%).

156 PLEASE INSERT FIGURE 2

157

158 When looking at psychological co-morbidities, anxiety and excessive stress are more often present in  
159 participants with some somatic influence (36.2 and 17.2%) and large somatic influence (40.9 and 18,3)  
160 compared to participants with no somatic influence (31.7 and 12.4%).

161 Presence of diagnostic criteria

162 As can be expected, overall, the diagnostic criteria for ST are significantly more present in participants  
163 with somatic influence than in participants with no somatic influence on their tinnitus. There are,  
164 however, some interesting results to point out.

165 Tinnitus modulation by voluntary movements of or pressure on certain areas of the head or neck was  
166 present in 74.2% of participants with large somatic influence, but also in 44.7% of participants with no  
167 somatic influence. The presence of neck pain and diagnosed temporomandibular disorders seems to  
168 be very typical for the group of participants with large somatic influence.

169 As for the tinnitus characteristics, the presence of a simultaneous onset and increase of both tinnitus  
170 and neck/jaw complaints is rather rare in the group of participants with no somatic influence, as is the  
171 increase of tinnitus during certain postures. The variation of tinnitus pitch, loudness and/or location is  
172 also more typical for participants with somatic influence, but especially tinnitus loudness variation also  
173 occurs in participants with no somatic influence.

174 Accompanying neck and jaw dysfunctions, such as myofascial trigger points, tension in neck extensor  
175 muscles and bruxism, are all far more prevalent in the groups with somatic influence. It must be noted,  
176 though, that they are also frequently present in participants with no somatic influence.

177 An overview of the details of these results can be found in supplement 3.

178 Diagnostic value of diagnostic criteria for somatosensory tinnitus  
179 In table 2, for each of the questioned diagnostic criteria, the sensitivity, specificity, positive and  
180 negative likelihood ratios and pre- and post-test probability are presented.  
181 When looking at the sensitivity and specificity values, it must be noted that specificity is generally high  
182 to very high, whereas sensitivity is low. This indicates, for all diagnostic criteria, that there is a low  
183 number of false positives, but a rather high number of false negatives.  
184 In general, the pre-test probability of ST diagnosis was 26%. This probability increases for each criterion  
185 that is present, where the absence of a criterion decreases the probability. The presence of a  
186 **simultaneous increase of both tinnitus and neck/jaw pain**, increases the probability to 79% (+LR:  
187 10,72). The presence of a **simultaneous onset** and **the influence of certain postures** increase the  
188 probability to 69% (+LR: 6,29) and 68% (+LR: 6,04) respectively. Furthermore, **the presence of**  
189 **myofascial trigger points**, a **head or neck trauma** and a **TMD diagnosis**, increase the probability to just  
190 above 50%. On the other hand, the **absence of neck pain** and the **absence of tension in the neck**  
191 **extensor muscles**, decreases the probability to 18% (-LR: 0,63) and 19% (-LR: 0,63) respectively.

## 192 Discussion

193 The aim of this study was to investigate the prevalence of each one of the diagnostic criteria for ST in  
194 a large group of people with tinnitus (ST and non-ST) and to further investigate the diagnostic value of  
195 these criteria, validate them empirically and identify their sensitivity and specificity.

196 In general, the 12 questioned diagnostic criteria for ST were more prevalent in patients with a somatic  
197 influence on their tinnitus compared to those without a somatic influence, as could be expected. It is  
198 important, though, to keep in mind that some of the criteria are also highly prevalent in patients with  
199 no somatic influence.

200 A first criterion, that has already led to discussions in the past, is the presence of tinnitus modulation.

201 Several authors have stated that **tinnitus modulation** should be present in order to define tinnitus as

202 somatic (Biesinger et al. 2015; Haider et al. 2017; Ward et al. 2015). This statement was already a point  
203 of discussion during the consensus meeting leading to the publication of the diagnostic criteria for ST  
204 in 2018 (S. Michiels et al. 2018). The consensus meeting panel agreed that, although somatic  
205 modulation (especially through voluntary movements) is an important criterion, it should not be used  
206 as a simple yes or no criterion for diagnosing ST. This statement is now confirmed by our current study  
207 results that show that somatic modulation is indeed more prevalent in patients with somatic influence  
208 on the tinnitus, but it also occurs in 44.7% of patients with no somatic influence. On the other hand,  
209 25.8% of patients with somatic influence on their tinnitus, do not experience somatic modulation. It  
210 must be noted that these percentages do not include somatic modulation through somatic  
211 manoeuvres (Biesinger et al. 2015), because they require physical testing and cannot be questioned in  
212 a survey. It might be possible that some of the patients with somatic influence on their tinnitus would  
213 experience tinnitus modulation during the somatic manoeuvres, but previous research has also shown  
214 a very high prevalence of tinnitus modulation during somatic manoeuvres in patients with no  
215 perceived somatic influence or even elicited a sound perception in controls without tinnitus (Abel et  
216 al. 2004). The diagnostic value analysis additionally shows that the presence or absence of somatic  
217 modulation through voluntary movements or pressure on the head or neck as a single criterion has  
218 very little value in ST diagnosis with a positive and negative likelihood ratio of 1.81 and 0.82  
219 respectively.

220 Another criterion (point of discussion in the consensus meeting panel as well) (S. Michiels et al. 2018)  
221 is **Tinnitus accompanied by frequent pain in the head, neck or shoulder girdle** or **Tinnitus**  
222 **accompanied by temporomandibular disorders**. The panel members stated that these criteria should  
223 be used with a certain prudence, because they also occur in patients with no somatic influence on their  
224 tinnitus (S. Michiels et al. 2018). This statement was again confirmed by our current analysis. The  
225 presence of these criteria increases the probability of ST diagnosis to about 50% when present, with  
226 positive likelihood ratios of 2.73 and 3.13. But, they seem to be more important to exclude ST diagnosis  
227 when absent (negative LR: 0.63 and 0.83). This is in accordance with previous research showing that

228 the absence of neck pain, defined as a score of less than 13 points on the Neck Bournemouth  
229 questionnaire, decreases the probability of neck related ST diagnosis to 19% (S. Michiels, Van de  
230 Heyning, P., Truijen, S., De Hertogh, W. 2015).

231 The presence of **a simultaneous onset or increase and decrease of tinnitus and neck/jaw problems**  
232 **and the influence of certain postures**, on the other hand, all have a very large positive likelihood ratio  
233 (6.29, 10.72 and 6.04 respectively). These criteria were already included in the first set of diagnostic  
234 criteria for ST, published by Sanchez et al. in 2011 (Sanchez et al. 2011). Additionally, the simultaneous  
235 increase and decrease of tinnitus and neck problems and the influence of certain postures were also  
236 identified as positive prognostic indicators for decrease in tinnitus severity after cervical spine  
237 treatment (S. Michiels et al. 2017). Therefore, we suggest to use these criteria as primary inclusion  
238 criteria in future studies on ST.

239 Further analysis of the diagnostic criteria, to identify a cluster of criteria with both high sensitivity and  
240 specificity, is planned and will be published in a separate paper.

241 Apart from differences in the prevalence of ST diagnostic criteria, our sample with somatic influence  
242 on their tinnitus also showed a significantly higher prevalence of hyperacusis, anxiety and excessive  
243 stress. The higher prevalence of hyperacusis in patients with ST is confirmed by a study on TRI data in  
244 2014 (Schecklmann et al. 2014), but was contradicted by a study of Cederroth et al. (Cederroth et al.  
245 2020) and Vielsmeier et al. Future studies investigating the prevalence of hyperacusis in patients with  
246 and without ST in a more controlled environment, using the Hyperacusis Questionnaire (Khalifa et al.  
247 2002), are needed to confirm our results, as the current information is based on a single question  
248 (question 13). (Vielsmeier et al. 2012). It would not be surprising that hyperacusis would be more  
249 prevalent in patients with ST, since hyperacusis also occurs as part of some chronic pain syndromes  
250 (such as fibromyalgia) that are more prevalent in ST than non-ST. Suhnan et al. (Suhnan et al. 2017)  
251 indicated that the central sensitisation, typical in chronic pain syndromes, may alter the activity at  
252 sensory convergence points in the thalamus and brainstem centres and give rise to hyperacusis.

253 The higher prevalence of anxiety and excessive stress in the ST groups has, to our knowledge, never  
254 been reported. A previous study by our group though, showed slightly higher percentages of a negative  
255 perceived effect by anxiety and stress on tinnitus severity in the ST group (S. Michiels et al. 2019).  
256 However, these differences were not significant. Although we could not find any supporting studies in  
257 literature, it seems logical that anxiety and excessive stress are more frequently reported in the ST  
258 groups. This, because both symptoms have also been reported to be more prevalent in neck pain and  
259 temporomandibular disorders (TMD), two conditions that are strongly associated with ST (Elbinoune  
260 et al. 2016; Kobayashi et al. 2017; Ortego et al. 2016; Schmitter et al. 2019; Sojka et al. 2019). Future  
261 research is needed to investigate if the higher prevalence of anxiety and excessive stress in ST is solely  
262 due to the higher prevalence of neck pain or TMD or if there are other explanatory mechanisms  
263 involved.

264 Additionally, our ST groups were characterized by a higher percentage of women and different tinnitus  
265 severity, loudness and type of sound compared to the non-ST group. The fact that women are more  
266 represented in the ST groups is in accordance with a previous study investigating the effect of gender  
267 on the effectiveness of tinnitus treatments (Van der Wal et al. 2020). This analysis also showed a more  
268 even distribution of men and women in a group of TMD related ST compared to a higher number of  
269 men in the other groups. Other studies also found a higher prevalence of women in ST (Vielsmeier et  
270 al. 2012), which can be explained by the higher prevalence of both neck pain and TMD in women (Hogg-  
271 Johnson et al. 2008; Marpaung et al. 2018).

272 The differences in tinnitus severity, loudness and type of sound, on the other hand, were not confirmed  
273 in the study of Vielsmeier et al. (Vielsmeier et al. 2012). Furthermore, other studies confirmed the  
274 absence of a difference in tinnitus severity, loudness and type of sound between patients with ST and  
275 other types of tinnitus (S. Michiels et al. 2019; S. Michiels, Van de Heyning, P., Truijen, S., De Hertogh,  
276 W. 2015; S et al. 2015). The differences between the current study and previous studies on the tinnitus  
277 severity and loudness, though, is that previous studies used averages to compare patients with ST to

278 patients with non-ST, while we used data from categorical values where no average can be calculated.  
279 This gives us more information on the distribution of our sample across the different tinnitus loudness  
280 and severity categories. Calculating averages would even out the observed differences.

281 The current study provides important information to aid the identification of patients with somatic  
282 influence on their tinnitus, but some limitations should be pointed out. As in every survey-based study,  
283 we largely rely on self-reported information, also for the identification of the somatic influence. This is  
284 why we did not use one single question to identify the magnitude of the somatic influence, but a  
285 combination of two questions, combining the diagnosis of the treating physician to the perception of  
286 the participant. Since the percentage of patients with somatic influence on their tinnitus in our sample  
287 strongly corresponds to the percentage we observe in the tinnitus clinic of the Antwerp University  
288 Hospital and to previously reported prevalence (Vielsmeier et al. 2012), we are convinced that our  
289 large sample size has evened out potential imperfections. Additionally, using the self-reported  
290 information on somatic influence has prevented us from too much circular reasoning. This is always a  
291 difficulty to overcome in diagnostic value studies on conditions where no objective diagnostic tests  
292 exist.

293 In conclusion, the simultaneous onset or increase and decrease of tinnitus and neck or jaw pain and  
294 the influence of certain postures, are most suited to use as a single criterion for identifying patients  
295 with a somatic influence on their tinnitus. On the other hand, the absence of neck pain or tension in  
296 the neck extensor muscles are good criteria to rule out a somatic influence. Additional analysis is  
297 needed to identify clusters of symptoms and criteria to further aid ST diagnosis. This analysis will be  
298 published in a separate paper.

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300 SM, HG and WS were responsible for the design of the study and composing the survey. SM additionally  
301 drafted the manuscript and contributed to the data processing and interpretation.

302 WS additionally contributed to the drafting of the manuscript and data interpretation. HG and MV  
303 were responsible for evaluating, launching and promoting of the survey and contributed to the drafting  
304 of the manuscript. EC was responsible for the data processing and contributed to the drafting of the  
305 manuscript and data interpretation. AG contributed to the drafting of the manuscript and the data  
306 interpretation.

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