Tinnitus, Anxiety and Automatic Processing of Affective Information: an Explorative Study

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CONFLICT OF INTEREST

None

ABSTRACT

Anxiety is found to play an important role in the severity complaint of tinnitus patients. However, when investigating anxiety in tinnitus patients, most studies make use of verbal reports of affect (e.g. self-report questionnaires and/or interviews). These methods reflect conscious appraisals of anxiety, but don't map underlying processing mechanisms. Nonetheless, such mechanisms, like the automatic processing of affective information, are important as they modulate emotional experience and emotion-related behaviour. Research showed that highly anxious people process threatening information (e.g., fearful and angry faces) faster than non-anxious people. Therefore, this study investigates whether tinnitus patients process affective stimuli (happy, sad, fearful, and angry faces) in the same way as highly anxious people do. Our sample consisted out of 67 consecutive tinnitus patients. Relationships between tinnitus severity, pitch, loudness, hearing loss, and the automatic processing of affective information were explored. Results indicate that especially in severely distressed tinnitus patients, the severity complaint is highly related to the automatic processing of fearful ($r = .37$, $p < .05$), angry ($r = .44$, $p < .00$), and happy ($r = -.44$, $p < .00$) faces and these relationships became even stronger after controlling for hearing loss. Furthermore, in contrast with findings on the relation between audiological characteristics (pitch and loudness) and conscious report of anxiety, we did find that the audiological characteristic, loudness, tends to be in some degree related to the automatic processing of fearful faces ($r = .25$, $p = .08$). We conclude that tinnitus is an anxiety-related problem on an automatic processing level.

INTRODUCTION

Tinnitus is often described as a ringing noise in the ear(s) or in the head, without the presence of external stimulation [1]. In some patients it takes the form of a buzzing, hissing, humming, or whistling sound, or as ticking, clicking, roaring, tunes, songs, etc. It has also been described as a "whooshing" sound, like wind or waves [2]. While clinical investigations have described help-seeking tinnitus patients as generally distressed by their tinnitus, epidemiological studies have shown that a large proportion of individuals with tinnitus do not seek medical or other professional help and appear not to be severely distressed by their affliction [3]. Several studies have indicated [4, 5] that at least two dimensions must be considered, namely the physical tinnitus symptom and its subjective experience or severity. However, the relationship between the tinnitus symptom and subjective severity seems to be asymmetric [5]: correlations between self-reported tinnitus severity and audiological characteristics (e.g. pitch and loudness) are usually nil. Conversely, strong correlations are often found between subjective tinnitus severity and psychological factors, such as anxiety. From this it is concluded that psychological factors, such as anxiety, are important in explaining the differences in the subjective severity

complaint [6]. In a previous study [7] we indeed found that tinnitus severity ratings, but not audiological tinnitus characteristics (pitch and loudness), are anxiety-related.

Yet, when investigating anxiety in a tinnitus population, most studies exclusively make use of direct measurement methods, such as self-report questionnaires and/or (structured) interviews [2, 6, 7]. These methods reflect conscious appraisals of anxiety, but don't map underlying processing mechanisms. Nonetheless, such mechanisms, like the automatic processing of affective information, are important as they modulate emotional experience and emotion-related behaviour [8]. Therefore, this study was designed to investigate the relation between tinnitus severity and anxiety on the level of automatic processing of affective information.

An influential method for measuring automatic processing of affective information is the affective priming paradigm of Fazio et al [9, 10]. This model [9, 11] proposes associative relations between representations of concepts and representations of their respective evaluation as having either a positive or a negative valence. It describes the process of automatic evaluation in terms of the spreading of activation between such representations. Central to this model is the difference between negative and positive evaluation of mental representations, and the idea that in a memory network concepts of the same valence are connected [12]. As a consequence, activation can spread between semantically unrelated but affectively congruent concept representations via the indirect links established in the form of the valence nodes. The idea that information is organized into associative networks in memory, is generally accepted within the broader domain of emotion research [13].

In an affective priming task, participants are first shown affectively polarized prime stimuli, like pictures of a smiling or sad face, for a very short period of time, typically ≤ 200 milliseconds (ms). These are followed by positive or negative target stimuli, like pictures of human injury or pleasant images of children, after which participants must evaluate the valence of the target as quickly and accurately as possible. The time it takes to make this evaluation is measured. The typically observed effect is the congruency or affective priming effect, qualified by a prime-target interaction: i.e. compared with reaction time to a baseline neutral prime, responses are facilitated when the valence of prime and target is congruent (e.g. "happy face" – "picture of the sun"), but are slower when the valence is incongruent (e.g. "angry face" – "picture of the sun") [9].

According to the network theory of mood and memory [12], the presence of any emotional state should trigger associated information in memory, leading to selective encoding of congruent stimuli. Studies have demonstrated that high levels of anxiety produce the expected affective priming effects, whereas low levels of anxiety result in reversed priming effects [14]. Furthermore, people with high trait anxiety proved to have stronger affective priming effects than people with low trait anxiety, which was specifically provoked by threat-

related primes [15]. Studies concerning attentional processes also demonstrated the presence of a threat-related bias in anxious patients [16]. These findings are consistent with theories on anxiety, where biases in processing threat-related information have been assigned a prominent role in the aetiology and maintenance of anxiety related problems [16, 17].

Facial expressions are particularly effective in alerting others to impending threat, with fearful and angry facial expressions as ecologically valid and salient depictions of threat [18, 19]. Anxious people are typically described as constantly scanning the environment for possible threats [16, 17, 20]. In terms of the affective priming task, such a threat-related bias may imply that anxious subjects are faster in deciding that a threatening stimulus is unpleasant [15], which is in line with network theory of mood and memory [12, 21].

Applied to the current study, the affective priming paradigm brings us to the research question whether tinnitus severity is related to the automatic processing of threatening information, which might corroborate the thesis that tinnitus is an anxiety-related problem. Therefore, we hypothesize that the automatic processing of threatening information (fearful and angry facial expressions) will be positively related to tinnitus severity. Furthermore we explore whether the latter hypothesis holds for all tinnitus patients, or only for those with high tinnitus-severity complaints. Usually, research on the relation between audiological characteristics (pitch and loudness) and self-reported anxiety find no relationships [4-7]. However, it remains possible that audiological characteristics are related to the automatic processing of affective information. We will study these relationships, but since this is the first study exploring this possibility, no specific assumptions are made. Additionally, we controlled for the possible influence of hearing loss in the severity complaint.

METHODS

Participants

The sample consisted of 81 consecutive tinnitus outpatients recruited from the Ear, Nose and Throat (ENT) Department of Ghent University Hospital. Five patients were unable to complete the experiment due to insufficient computer knowledge. Another nine patients were outliers and were excluded from analysis on the basis of mean reaction time (< 250 ms or > 1500 ms). The mean age of the 67 remaining patients was 48.63 years old (SD = 12.74); 37.3% were women; average duration between onset of tinnitus and inclusion in the study was 44.18 months (SD = 58.26). All patients underwent a thorough ENT examination and, if necessary, imaging of the ear and central auditory system. All patients were seen by a psychologist. In 15 patients psychoacoustic measures failed. The reason for this failure was the inability of patients to match their pitch and loudness. There were no significant differences between the subsample where psychoacoustic measures failed with respect to sex, mean age or mean duration (p > .05).

The study protocol was approved by the ethical committee of Ghent University Hospital and was in accordance with the Helsinki Declaration.

Measures

Tinnitus Handicap Inventory (THI) [22]*:* To evaluate the impact of tinnitus on daily life, the Dutch version of the THI was administered. This scale is composed of 25 questions and the scores can vary between 0 and 100. The THI specifies different ranges of an index score, namely *light* (0-16), *mild* (18-36), *moderate* (38-56), *severe* (58-76) and *catastrophic* (78-100) handicap. Cronbach's alpha was .92 indicating very good internal consistency, comparable to the original version of the THI [22].

The anxiety trait scale of the Dutch version of *the State and Trait Anxiety Inventory (STAI)* [23] was used to measure anxiety. The scale consists of two 20-item self-report scales for trait anxiety. Spielberger [24] defined 'trait anxiety' as relatively stable individual differences in anxiety proneness and refers to a general tendency to respond with anxiety. For each symptom, statements are listed in ascending order, from 1 (almost never) to 4 (almost always). There is a total score for trait anxiety. The psychometric properties of the Dutch version of the questionnaire are very good [23]. Internal consistency in this sample was also very good with $\alpha =$ .96 for trait anxiety. For each patient scores on the scale can be compared with a Dutch norm group (different for men and women). This means that raw scores can be converted into decile scores ranging from 1 to 10 whereby a score of 5 is considered average, a score of 10 is very high and a score of 1 is very low [23].

The two *psychoacoustic measures* used in this study were pitch and loudness matching. Pitch matching attempts to quantify tinnitus in terms of its possible frequency (kilohertz; kHz). The procedure is a two-alternative forced choice. Two tones are presented to the patient and the patient is asked to choose which one most closely matches the tinnitus that they hear. This is continued until the match is made. Next, an octave confusion test is performed. This is the phenomenon where the patient has identified one tone as matching the tinnitus, when, with further testing, the match is actually one octave above or below the tone. The loudness matching is the psychoacoustic equivalent of sound intensity. Therefore, this test attempts to quantify the tinnitus in decibels (Decibels Sensation Level; dB SL). The procedure for loudness matching starts at a level just below threshold and intensity is increased until the patient signals a match. The frequency that was matched to the patient's tinnitus is used. Matching stimuli were presented using an Interacoustics Clinical Audiometer AC 40 (Interacoustics A/S, Denmark) in a sound proof booth.

Hearing loss was measured with pure tone audiometry. The pure tone average (PTA) was calculated across the frequencies 0.5, 1.0, and 2.0 kHz. Since this method fails to account for hearing loss at higher frequencies, a second PTA across the frequencies 4.0, 6.0, and 8.0 kHz was calculated. Normal hearing was

defined as PTA (0.5-1.0-2.0) < 15dB HL (Hearing Level) and for higher frequencies as PTA (4.0-6.0-8.0) < 30dB HL [25].

Affective priming task: Stimuli. Target stimuli were 7 positive and 7 negative pictures from the International Affective Picture System (IAPS) [26]. Selection was based on a Flemish validation study [27]. The 7 most positively and negatively rated pictures on valence were selected for this study. Prime facial stimuli were 6 fear, 6 angry, 6 sad, 18 happy and 6 neutral facial pictures from the Karolinska Directed Emotional Faces (KDEF) [28]. The KDEF-database shows pictures of 70 individuals (35 women and 35 men) displaying 7 different emotional expressions (Angry, Fearful, Disgusted, Sad, Happy, Surprised, and Neutral). Selection was based on a Flemish validation study [18], which used the frontal view pictures of the A series for their validation. To minimize fashion characteristics, the hairlines of all pictures were removed. For each emotion used in this study (fear, anger, sadness, happiness and neutral), we selected the best rated facial expressions for men and women. In this way the amount of men and women expressing each emotion was balanced.

Procedure. Subjects were informed that they would be presented with sets of positive and negative pictures. The instruction was to evaluate the pictures as quickly and accurately as possible. Response latencies were recorded by pressing one of two response buttons (left, right) on a control pad. Each trial had the same routine: The prime was presented for 180 ms, preceded by a dot lasting 150 ms. The prime was erased lasting 20 ms, after which the target was immediately presented. This led to a stimulus onset asynchrony of 200 ms between prime and target presentation. The pre-trial pause was 600 ms. There were 3 exercise blocks and 4 experimental blocks. The first exercise block consisted of 20 trials of target stimuli only. If the target was incorrectly evaluated, an error message was given. The second exercise block consisted of 20 prime-target trials, again an error message appeared when the target was incorrectly evaluated. The last exercise block consisted of 60 prime – target trials. If the number of correct answers was < 75%, this exercise block would be repeated for a maximum of 5 times. The purpose of these exercise blocks was that patients could get used to the experiment and thus, these data were removed for data analyses. The 4 experimental blocks each consisted of 84 trials. In each block the amount of positive (happy faces) and negative (fearful, angry, sad faces) primes was balanced. For each emotion prime stimuli were randomly assigned to the 14 targets so that 18 affective congruent happy face (happy-pos), 18 affective incongruent happy face (happy-neg), 6 affective congruent fearful face (fear-neg), 6 affective incongruent fearful face (fear-pos), 6 affective congruent angry face (angry-neg), 6 affective incongruent angry face (angry-pos), 6 affective congruent sad face (sad-neg), 6 affective incongruent sad face (sad-pos), and 12 control trials (6 neutral face-pos, 6 neutral face-neg) were generated separately for each block. Pictures were presented full-screen on a computer (1280 x 1024 pixels). Subjects could take a break after each block.

RESULTS

Descriptives

Mean scores on subjective tinnitus severity, trait anxiety, and audiological characteristics are presented in table 1. For the THI 13.4% (*n*=9) of the sample reported a light handicap; 26.9% (*n*=18) reported a mild handicap; 29.9% (*n*=20) reported a moderate handicap; 22.4% (*n*=15) reported a severe handicap; and 7.5% (*n*=5) reported a catastrophic handicap.

Table 1: Mean scores (M), standard deviations (SD), and range values for the Tinnitus Handicap Inventory (THI), Trait anxiety of the State and Trait Anxiety Inventory (STAI-trait), audiological characteristics (Pitch and Loudness), and hearing loss (PTA (0.5-1.0-2.0) and PTA (4.0-6.0-8.0)

	M	**SD**	**Range**
THI[a]	43.88	21.86	4 – 96
STAI-trait[a]	42.13	12.30	20 - 70
Pitch[b] (kHz)	4.41	2.76	125 - 11200
Loudness[b] (dB SL)	7.75	5.66	0 – 30
PTA (0.5-1.0-2.0)[b] (dB HL)	16.65	11.38	1.67 – 61.67
PTA (4.0-6.0-8.0)[b] (dB HL)	39.15	19.81	5 - 90

Note: kHz = kilohertz; dB SL = decibel sensation level; PTA= Pure Tone Average; dB HL = decibel hearing level; [a] total sample (*N*= 67); [b] sub-sample (*n*=52)

Following the STAI-manual, 9% (*n*=6) had a very low score; 21% (*n*=14) a low score; 9 % (*n*=6) an average score; 29.8% (*n*=20) a high score; and 31.3% (*n*=21) had a very high score for trait anxiety.

Furthermore, 50% of the sample (*n*=26) where audiological measures succeeded had normal hearing at the averaged frequency levels (0.5-1.0-2.0) and 36.5% (*n*=19) had normal hearing at averaged high frequency levels (4.0-6.0-8.0). In total 26.9% (*n*=14) had normal hearing on each frequency level.

Table 2: Correlations between the Tinnitus Handicap Inventory (THI), Trait anxiety of the State and Trait Anxiety Inventory (STAI-trait), audiological characteristics (Pitch and Loudness), and hearing loss (PTA (0.5-1.0-2.0) and PTA (4.0-6.0-8.0))

	THI	**STAI-trait**	**Pitch**	**Loudness**	**PTA (0.5-1.0-2.0)**	**PTA (4.0-6.0-8.0)**
THI	1					
STAI-trait	.51[***/a]	1				
Pitch	.17[b]	-.03[b]	1			
Loudness	-.02[b]	.13[b]	-.31[*/b]	1		
PTA (0.5-1.0-2.0)	.34[*/b]	.08[b]	-.11[b]	-.21[b]	1	
PTA (4.0-6.0-8.0)	.41[***/b]	-.09[b]	.12[b]	-.14[b]	.71[***/b]	1

Note: PTA= Pure Tone Average; *= $p < .05$; ***= $p < .00$; [a] total sample (*N*= 67); [b] sub-sample (*n*=52)

Table 2 gives an overview of correlations found between the THI, STAI-trait, audiological characteristics (pitch and loudness), and hearing loss. Positive significant correlations were found between the THI and STAI-trait, and between the THI and hearing loss.

Affective priming results and priming indices

Mean reaction times were subjected to a 4 (valence of prime: happy, sad, fearful, angry faces) x 2 (valence of target: positive vs. negative pictures) ANOVA with repeated measures on the two variables. ANOVA revealed a significant interaction effect between valence of the prime and valence of the target (prime x target), $F(3,63) = 6.89$, $p < .05$, $\eta_p^2 = .25$, meaning that the affective priming effect can be observed for the different valences of the prime. The main effects of prime valence and target valence did not reach significance ($F < 1$).

Four indices were computed to examine the influence of the prime types (happy, sad, fearful, and angry face) on patients' evaluations. The indices were calculated in such a way that we controlled for the influence of the valence of the target. The following formula was used [29]:

1. Influence of positive (happy face) primes = [(positive prime-negative target) – (positive prime-positive target)] – [(neutral prime-negative target) – (neutral prime-positive target)]

2. Influence of negative (sad, fearful, and angry faces) primes = [(negative prime-positive target) – (negative prime-negative target)] + [(neutral prime-negative target) – (neutral prime-positive target)]

The relation between affective priming indices (happy, sad, fearful, angry faces) and tinnitus (severity complaint and audiological characteristics): overall results

Table 3 gives an overview of correlations found between the affective priming indices and tinnitus severity at the level of the total sample. A negative significant correlation was found between the THI and the happy face prime, meaning that the affective priming effect of happy faces becomes smaller as patients' THI score increases. No correlations were observed between other prime types and tinnitus severity ($p > .05$). Since the THI was correlated with hearing loss, we repeated our analyses while controlling for hearing loss on the two average frequencies separately. Results of partial correlations (table 4) showed that the negative correlation between the THI and the happy face prime became stronger. Moreover, after controlling for hearing loss at normal frequencies (PTA (0.5-1.0-2.0)) the relation between the THI and anxious face became marginally

Table 3: Correlations between the Tinnitus Handicap Inventory (THI) and the affective priming indices for happy, sad, fearful, and angry faces (*N*=67).

	Happy face primes	Sad face primes	Fearful face primes	Angry face primes
THI	-.27*	-.03	.16	.11

Note: *p< .05

Table 4: Partial correlations between the Tinnitus Handicap Inventory (THI) and the affective priming indices for happy, sad, fearful, and angry faces controlled for PTA (0.5-1.0-2.0) and PTA (4.0-6.0-8.0) separately (*n*=52).

		Happy face primes	Sad face primes	Fearful face primes	Angry face primes
	Control variable				
THI	PTA (0.5-1.0-2.0)	-.36**	.08	.25■	.22
THI	PTA (4.0-6.0-8.0)	-.31*	.04	.29*	.17

Note: PTA = Pure Tone Average; *p<.05; **p<.01; ■p = .07

significant, while after controlling for hearing loss at high frequencies (PTA (4.0-6.0-8.0)) the relation between the THI and anxious face became significant.

Furthermore, a marginal positive correlation was found between the psychoacoustic characteristic, loudness, and the anxious face prime (r=.25, p=.08), meaning that the affective priming effect of anxious faces becomes higher as patients' experienced loudness increases. No correlations between other prime types and loudness, or pitch were observed (p>.05).

The relation between affective priming indices (happy, sad, fearful, angry faces) and tinnitus severity: results for patients with low and high tinnitus severity complaints

In a next step, the total sample was divided into two subgroups: a group with slight/mild tinnitus severity (THI score < 38) and a group with moderate, severe or catastrophic tinnitus severity (THI score ≥ 38) [30]. Again the THI was correlated with the four indices for influence of prime types (happy, sad, fearful, angry face). The analyses were performed for each group (low / high tinnitus severity) separately. For the low tinnitus severity group no relationships between prime types and the THI were found. Table 5 depicts the results for the high tinnitus severity group. The THI score was positive related to fearful and angry faces, and negative related to happy faces. No relation with sad face was observed (p > .05). Since the THI was correlated with hearing loss, we repeated our analyses while controlling for hearing loss on the two average frequencies separately. Results of partial correlations are depicted in table 6. These results indicate that in patients with severe distress, tinnitus

Table 5: Correlations between the Tinnitus Handicap Inventory (THI) and the affective priming indices for happy, sad, fearful, and angry faces for the high tinnitus severity group (THI ≥ 38) .

	Happy face primes	Sad face primes	Fearful face primes	Angry face primes
THI	-.44***	.18	.37*	.44***

Note: *p<.05; ***p<.00

Table 6: Partial correlations between the Tinnitus Handicap Inventory (THI) and the affective priming indices for happy, sad, fearful, and angry faces controlled for PTA (0.5-1.0-2.0) and PTA (4.0-6.0-8.0) separately for the high tinnitus severity group (THI ≥ 38).

	Control variable	Happy face primes	Sad face primes	Fearful face primes	Angry face primes
THI	PTA (0.5-1.0-2.0)	-.54***	.28	.45**	.53***
THI	PTA (4.0-6.0-8.0)	-.50***	.19	.48***	.50***

Note: PTA = Pure Tone Average; **p<.01; ***p<.00

severity is accompanied by an increasing impact of fearful and angry face primes, and by an decreasing impact of happy face primes, and this impact became even stronger after controlling for hearing loss.

DISCUSSION

In this study, we investigated the relationship between automatic processing of affective information and tinnitus severity. We hypothesized a positive relationship between automatic processing of threat-related information. Furthermore, we explored whether these predictions hold true for the total tinnitus sample or only for patients reporting severe tinnitus complaints. For audiological characteristics, pitch and loudness, we explored whether relations could be found with the automatic processing of affective information.

In line with former research, tinnitus severity and self-reported anxiety are highly related [6, 7], indicating that tinnitus severity is an anxiety-related problem. As expected, no relations were found between tinnitus severity and audiological characteristics (pitch and loudness), or between self-reported anxiety and audiological characteristics (pitch and loudness) [6, 7]. There were however positive correlations between tinnitus severity and hearing loss on each averaged frequency level, meaning that the more hearing loss patients have, the higher the severity complaint is.

Overall, our results indicate the presence of an affective priming effect: reaction times were shorter when the prime and the target had the same valence than when the valence of prime and target was opposite.

This was indicated by a significant prime x target interaction and corroborates previous findings in affective priming tasks [10, 11]. This result confirms the validity of the material designed for the present study.

For the total sample our results suggest that subjectively rated tinnitus severity is related to disruptions in the automatic processing of positive affective information, but not to the processing of negative affective information. However, after controlling for hearing loss at normal frequencies (PTA (0.5-1.0-2.0)), the negative relation between the THI and happy faces became stronger and the correlation between the THI and anxious faces became marginal significant. Also after controlling for high frequency hearing loss (PTA (4.0-6.0-8.0)), the negative relation between the THI and happy faces became stronger and the relation between the THI and anxious faces became significant. The negative relation between priming effects of pleasant stimuli and tinnitus severity may give an indication of the impact of tinnitus on the quality of life. In clinical practice many patients report withdrawing from pleasant social activities as a result of tinnitus and often co-morbid hearing disability: like difficulty following conversations, irritation by surrounding noises etc., which possibly leads to perceiving such activities as unpleasant and to experiencing less positive emotion. This might explain why it takes longer for them to react to positive emotional stimuli as tinnitus severity increases. Alternatively priming effects to positive affective stimuli might indicate that distressed tinnitus patients feel more ambivalent about positive emotions, and thus take longer to process these. Some researchers have argued that smaller priming effects to positive stimuli are associated with anxiety [14, 21], while others have found that non-depressed (in comparison with depressed) subjects demonstrated a bias toward the positive stimuli [31]. However, a direct relationship between tinnitus severity and anxiety-related stimuli (fearful faces) for the total sample could only be established after controlling for hearing loss, which implicates that hearing loss obfuscates the relation between tinnitus severity and the processing of fearful faces. Moreover a remarkable trend could be observed between the audiological characteristic, loudness, and the automatic processing of fearful faces. The reason why this trend was not significant, could be our smaller sample size. As mentioned, not all patients were able to match pitch and loudness, and thus we lost some statistical power. However, the result indicates that as patients experience more loudness, a stronger priming effect of the threat-related cues (fearful faces) emerges. These findings suggests that tinnitus severity and loudness, cohere with the processing of fear-related stimuli on an automatic level. A possible explanation, why only fearful faces are related and not threat-related stimuli in general, could be that tinnitus severity and loudness are accompanied specifically with a fear reaction in memory. Although this interpretation should be tested for in future research, we believe it is consistent with verbal reports in clinical practice, where patients are afraid that the tinnitus and specifically the loudness gets worse.

In a next step we studied our hypothesis in the subgroup of patients with severe tinnitus complaints and the subgroup with mild tinnitus-severity complaints separately. In the high scoring group tinnitus severity was positively related to fear and anger stimuli and negatively to positive emotion stimuli, which was in line with our hypothesis. In this subgroup stronger tinnitus-severity complaints are accompanied by stronger affective priming of threat-related information and weaker affective priming for positive affective information and these relations became stronger after controlling for hearing loss at normal and high frequency levels. This result is in line with the study of Li et al [15], who found especially stronger affective priming driven by threatening stimuli for subjects with high trait anxiety as compared to those with low trait anxiety. Furthermore, we found normal priming effects and not reversed ones, which is in line with former research findings [14] where affective priming was found in people with high trait anxiety, and reversed priming effects in people with low trait anxiety. Moreover, these results converge with research concerning threat-related biases in highly anxious subjects [16].

Overall, these findings show that especially in patients with severe tinnitus distress, symptom severity is an anxiety-related problem independent from the amount of hearing loss. For patients with mild tinnitus distress this did not prove to be true.

We believe that this result has important theoretical and clinical implications: the presence of a threat-related bias suggests that distress associated with tinnitus severity is an anxiety-related problem, and not a depression-related problem. If tinnitus severity was related to depression, one would expect a bias towards the sad faces. Indeed, in previous studies such bias towards sad faces proved to be typical for depressed patients, but not for anxious patients [20]. Likewise in previous studies depressed patients did not show the kind of threat-related bias that is typical of anxiety [14, 20]. The results of this study corroborate the suggestion of Ooms et al. [32] that the frequently observed relation between tinnitus severity and depression is an artefact of method bias and content overlap between questionnaires. However, results on mood congruency effects in depression are contradictory [21], and thus caution is still warranted in drawing conclusions in this respect.

Since this study is a correlation study, statements upon the directionality between tinnitus severity and the automatic processing of threatening information cannot be made. However, based on former research [33, 34], theory [35] and clinical practice, we believe that the automatic processing of threatening information may exist before the tinnitus becomes chronic. Support for this idea can be found in former research, which indicates that anxiety-related personality disorders are common in tinnitus patients [36]. Probably these patients also have a more anxious reaction to the tinnitus signal. In this way, a vicious circle is created whereby anxiety as causal

factor and anxiety as reactive factor stimulate each other. Yet, we believe that the exact direction between tinnitus severity and anxiety can only be decided on an individual level.

Limitations of this study concern our interpretation of the affective priming effects via network theory and the idea of spreading activation. This theory is contested by some authors [10]. Another explanation for priming effects is the stroop mechanism, where automatic and strategic components reflect priming effects [10]. However, in our interpretation the notion of spreading activation and the stroop mechanism are not opposed to each other. As Fazio [11] argues, rather than opposing each other, these theories are complementary. Moreover, we did not make use of a masking procedure to overcome possible strategic responding [10] putting the 'automaticity' of our results into question. However, this cannot explain the different priming patterns associated with tinnitus severity, since strategic responding can be considered to have the same impact for the whole sample. Furthermore, as we didn't replicate our experiment, it remains possible that these results were obtained by chance. Yet, this is the first study on automatic processing of affective information with a tinnitus population, and our results fit the clinical observation that patients with severe tinnitus complaints typically suffer from anxiety related symptoms such as feeling more anxious, restless, irritable, having poor concentration and difficulty sleeping [37, 38].

This study principally points to the importance of processing of threatening information in tinnitus patients. Moreover, a different pattern in the processing of affective pictural stimuli between patients with low versus high tinnitus severity scores was found. In patients with severe distress, tinnitus severity scores are clearly connected with a bias towards threatening information and which is independent from the amount of hearing loss. This is consistent with findings in highly anxious subjects, and indicates that in severely distressed patients tinnitus severity is also an anxiety-related problem on an automatic level. Furthermore, the audiological characteristic, loudness, also tends to be in some degree an anxiety-related problem. Yet, future research needs to confirm the obtained results and should focus on the directionality between anxiety and tinnitus (severity).

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