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ORIGINAL ARTICLE

Tinnitus affects the relative roles of semantics and prosody in the perception of emotions in spoken language

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ABSTRACT

Objective: Understanding communication difficulties related to tinnitus, by identifying tinnitus-related differences in the perception of spoken emotions, focussing on the roles of semantics (words), prosody (tone of speech) and their interaction.

Study sample and design: Twenty-two people-with-tinnitus (PwT) and 24 people-without-tinnitus (PnT) listened to spoken sentences made of different combinations of four discrete emotions (anger, happiness, sadness, neutral) presented in the prosody and semantics (Test for Rating Emotions in Speech). In separate blocks, listeners were asked to attend to the sentence as a whole, integrating both speech channels (gauging integration), or to focus on one channel only (gauging identification and selective attention). Their task was to rate how much they agree the sentence conveys each of the predefined emotions.

Results: Both groups identified emotions similarly, and performed with similar failures of selective attention. Group differences were found in the integration of channels. PnT showed a bias towards prosody, whereas PwT weighed both channels equally.

Conclusions: Tinnitus appears to impact the integration of the prosodic and semantic channels. Three possible sources are suggested: (a) sensory: tinnitus may reduce prosodic cues. (b) Cognitive: tinnitus-related reduction in cognitive processing. (c) Affective: group differences were related to the existence of tinnitus, but not to the extent of tinnitus complaints and/or affective symptoms.

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Tinnitus; speech; speech perception; emotion; cognition

Introduction

Tinnitus is the perception of sounds, without any external stimulus. Its prevalence in the general population has been estimated to be between 8 and 30% (Richardson and Flint 2010). Some patients consider the tinnitus to be insignificant, while for others, the tinnitus becomes intrusive, affecting and changing their lives (McCormack et al. 2016). For these patients, communication disorders and impaired social interactions present a major source for discomfort (Folmer and Carroll 2006). Recently, the literature suggests that the difficulties people-without-tinnitus (PnT) experience in spoken communication may emanate from impaired processing of emotions in speech (Ben-David et al. 2016; Zupan et al. 2009; e.g. in aging Dupuis and Pichora-Fuller 2014; Paulmann, Pell, and Kotz 2008). However, little is known about processing of emotions in speech in People-with-Tinnitus (PwT). The goal of this study is to fill this gap, directly examining how PwT process emotions as expressed by the semantics (words), the prosody (tone of speech) and the interaction between them. This is of specific importance, as there are indications in the pertinent literature, that tinnitus may affect factors involved in the processing of emotions in speech (reduced identification of some emotional-speech cues, and difficulties in inhibiting information). This study is the first systematic examination of the perception and integration of semantic and prosodic emotional cues in PwT.

Perception of emotions in speech

Spoken communication, and specifically the processing of emotions in spoken language, has an important role in daily social interactions (Ben-David, Thayapararajah, and van Lieshout 2013; Loveland et al. 1997). Clearly, when the listener does not fully comprehend the emotion conveyed by the speaker, miscommunication ensues, with possible negative implications on the quality of life and social well-being (Hudepohl et al. 2015). Tinnitus has been related to reduced social interactions (Durai, O'Keeffe, and Searchfield 2017; Durai and Searchfield 2016). Thus, assessing the possible difficulties engendered by tinnitus in this function could provide paths to improve communication and PwT's quality of life.

The perception of spoken emotions involves the integration of several channels, including visual and auditory. When visual

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Supplemental data for this article can be accessed here.

information is absent (e.g. when talking over the phone) or when it is partial or degraded (e.g. due to sensory degradation: Ben-David and Schneider 2010), the ability to derive emotional meaning from spoken language relies on how it is conveyed in two auditory speech channels: the semantic channel (the meaning of the words) and the prosodic channel (tone of speech, intonation of voice, indexical cues). In typical conversations, emotional semantic and prosodic cues are often matched, making it difficult to determine the relative roles of each channel. However, in mismatched sentences, when the emotions presented by the semantics and prosodic channels do not match, identification of spoken emotions is especially challenging (Ben-David, Van Lieshout, and Leszcz 2011).

To illustrate, imagine a PwT receiving a phone call from his PnT colleague, saying "I feel wonderful today" spoken with angry prosody. Such a conflicting message may be interpreted in different manners. Would a PwT interpret the message as an expression of happiness, anger, or a combination of the two? More generally, do PwT differ than PnT in the way they perceive, identify and integrate verbal and prosodic emotional cues? Do PwT assign the same relative weights as PnT to the two speech channels? Indeed, to the best of our knowledge, no study to date has tested the perception and integration of semantic and prosodic channels in this population.

To gauge separately the role of each channel in the perception of emotions in speech, Ben-David and his colleagues developed the *Test of Rating of Emotions in Speech* (*T-RES*, Ben-David et al. 2016), as depicted in Figure 1. In the T-RES, participants are presented with spoken sentences in which the emotional semantics and prosodic content appear in different combinations from trial to trial. Listeners are asked to rate the extent to which each sentence conveys a predefined emotion. After testing 80 healthy adults (that did not complain of any auditory symptoms), Ben-David et al. (2016) came to three main conclusions: (1) *Identification of emotions*. Participants successfully identified the emotions expressed in the prosody and lexical content separately; (2) *Selective attention*. Participants failed to selectively attend to one channel, while actively ignoring the other; (3) *Prosodic dominance*. Listeners process the emotional content of spoken language as a whole, and their interpretation is affected by both the prosodic and semantic channels. However, the prosody of speech appears to have a larger impact on emotional ratings than semantics (see also, Jacob et al. 2014; Mehrabian and Wiener 1967).

The three factors pointed above (identification of emotions, selective attention and prosodic dominance) have not been directly examined in the literature in relation to tinnitus. In the next sections, we review the existing evidence in the literature, Vis a Vis the possible effects of tinnitus on the perception of emotions in spoken language.

Tinnitus-related effects: identification of semantics and prosodic emotional cues

Semantics

The tinnitus symptom is an internal interfering sound (Andersson 2002) which might mask a similar frequency range in the source stimulus, such as target speech. As a consequence, tinnitus may be considered as generating internal energetic masking. Energetic masking occurs when the energy in the masker is high enough to overwhelm the energy emanating from the target speech, in regions of spectral overlap, making segments of the target speech inaudible (Pichora-Fuller and Souza 2003). Indeed, there is ample literature to suggest that spoken word identification is reduced when speech is presented on the background of a constant noise. For example, a recent study indicates that even when the auditory system has "adapted" to the interfering noise (after 300 ms), spoken word recognition is significantly impaired (Ben-David, Avivi-Reich, and Schneider 2016; Ben-David, Tse, and Schneider 2012).

In our literature search, we were not able to locate a study that directly tested the ability of PwT to accurately identify emotional semantic cues. However, previous findings suggest that PwT are generally less accurate than PnT in identifying spoken words (Hennig et al. 2011), especially in adverse conditions (Goldstein and Shulman 1999; Huang et al. 2007; Newman et al. 1994). For example, in a large scale study by Vielsmeier et al. (2016), ~80% of PwT complained about speech comprehension difficulties in noise, and ~40% about speech comprehension difficulties in general. Indeed, ~75% of the tested PwT group in that study were found to have difficulties in spoken sentence comprehension. Notably, Gilles et al. (2016) found a similar tinnitus-related decrease in spoken-word identification, even when the group of PwT and PnT were matched on pure-tone audiometric thresholds. A recent literature review found that the vast majority (12 out of 13) of pertinent studies reported impairments in speech perception in patients suffering from chronic tinnitus (Ivansic et al. 2017). These tinnitus-related difficulties in spoken word identification may interrupt the processing of the semantic content and reduce the ability to correctly perceive emotion-related words. For example, misperceiving "I feel *mad*" for "I feel *sad*" can alter the emotional meaning of a sentence, leading to greater difficulties in processing emotions in speech (for similar effects of offset overlap confusion, in English: Ben-David et al. 2011; Hebrew: Hadar et al. 2016).

Prosody

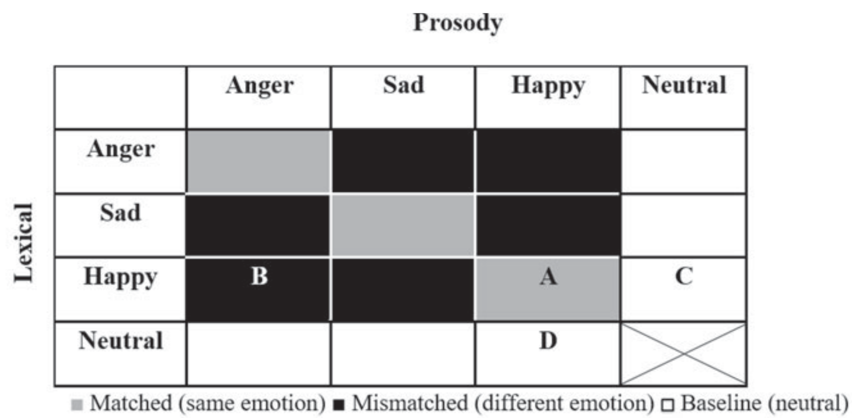
To the best of our knowledge, no study directly tested the ability of PwT to identify prosodic cues in general, or emotional prosodic cues specifically. Yet, there are a few studies suggesting that PwT have reduced sensory processing abilities that may impair their ability to detect acoustic features that serve as prosodic cues (Dmitrieva and Gelman 2012). For example, Jain and Sahoo (2014) found evidence for tinnitus-related reduced performance in the following psychoacoustic measures: temporal resolution, frequency discrimination, and modulation detection thresholds. There is also evidence to suggest that gap detection, a measure related to prosody identification (Pichora-Fuller and Souza 2003), may be reduced in PwT (Fournier and Hébert 2013; Gilani et al. 2013; Haas, Smurzynski and Fagelson 2012; Sanches et al. 2010; but see, Acrani and Pereira 2010; Boyen, Başkent, and van Dijk 2015).

In addition, tinnitus may impair the accuracy of spoken-word processing, due to internal energetic masking, limiting the ability to process emotions presented in the semantic channel. It may also impair processing of semantic cues due to reduced sensory processing.

Tinnitus-related effects: failures of selective attention and integration of channels

Tinnitus was found to impair performance in standardised tests of selective attention in the visual domain, such as the fore-period reaction time (Hallam, McKenna, and Shurlock 2004), colour-word Stroop test (Stevens et al. 2007) and Posner's

General design of the stimuli



A. Matched: lexically happy ("Congratulations, you are hired") with matched happy prosody	
B. Mismatched: lexically happy ("You have got first place") with mismatched angry prosody.	
C. Baseline (lexical): lexically happy ("This is my favorite part") with neutral prosody.	
D. Baseline (prosody): lexically neutral ("Red pipes are metallic") with happy prosody.	

Rating tasks

General rating task	Prosodic rating task	Semantic rating task
Participants are asked to rate the overall emotion of the sentence as a **whole**.	Participants are asked to rate the sentence based only on the **prosody** ignoring the semantic content.	Participants are asked to rate the sentence based only on the **semantic** content, ignoring the prosody.
Set 1 with 15 sentences	Set 2 with 15 sentences, presented in both tasks.	
This task measures the relative weighting of the semantic and prosodic channels.	These tasks (resembling Stroop-like tasks) gauge differences in selective-attention. Baseline (neutral) sentences measure the identification of emotions.	

Rating blocks

Each rating task is made up of four emotional rating blocks, comprising 12 experimental blocks. On each trial, listeners are asked "From 1 (strongly disagree) to 6 (strongly agree)…"

Anger-rating	Sadness-rating	Happiness-rating
"…to what extent do you agree that the speaker conveys **anger**?"	"…to what extent do you agree that the speaker conveys **sadness**?"	"…to what extent do you agree that the speaker conveys **happiness**?"

Figure 1. General design of the T-RES. All combinations of prosody and lexical (16) are presented in each emotional rating block (Note: neutral semantic spoken with neutral prosody was deemed uninformative and was not presented. For more information see Ben-David et al. 2016). The shaded rows in the bottom present examples for each type of combination.

visual Attention Network Test (Heeren et al. 2014). This deficit in (visual) selective attention is considered to be related to a more central source, rather than to a certain sensory domain. In their review of the literature, Mohamad, Hoare, and Hall (2016) suggest that the irrelevant sounds, characterising the tinnitus phenomenon, may hamper selective attention by depleting available attentional resources in PwT (see also Banbury et al. 2001), or by slowing cognitive processing (Andersson et al. 2000; Jackson, Coyne, and Clough 2014). More generally, a recent systematic review of the literature (Tegg-Quinn et al. 2016) suggests that tinnitus impairs executive functions (encompassing both selective attention and integration). The authors suggest that decreased inhibition and selective attention performance in PwT is not only related to the interfering sounds but also to neuroanatomical changes (Araneda et al. 2015; De Ridder et al. 2011; Rauschecker, Leaver, and Mühlau 2010). In the auditory domain, the evidence on tinnitus-related decreased attentional performance are not consistent. Some studies found no statistically significant differences between PwT and PnT on auditory selective and divided attention tasks (Acrani and Pereira 2010; Shakarami et al. 2015), while other studies indicated tinnitus-related changes in auditory selective attention (Jacobson et al. 1996).

Reduced ability to manipulate and control auditory attention may affect the processing of emotions in speech, when the task calls for integration of the semantic and prosodic channels or for selective attention to one channel, while inhibiting the other.

Tinnitus-related changes, both in sensory and in cognitive abilities, might impair the integration of semantic and prosodic channels. As aforementioned, when the semantics and prosody present different emotions, healthy young listeners are biased to over-weigh the prosody, and under-weigh the semantics. To achieve this, the listener must process the prosodic emotional information quickly and efficiently, while inhibiting the (incongruent) semantic emotional content. If PwT are less efficient than PnT in processing prosodic cues, and/or if they are less efficient in inhibiting contrasting information (in this case, semantic), they may have difficulties in this task. Namely, the extent of prosodic dominance, the difference between ratings on the prosodic and semantic channel, will be smaller for PwT than for PnT.

The current study

Tinnitus leads to disturbance to daily life, specifically affecting social communication. The current study focuses on gauging impairments in the perception of emotions in speech, as a possible source for the difficulties PwT experience in communication. We compare performance between PwT and a matched group of PnT on the T-RES, using a Hebrew adapted version (Shakuf et al. 2016). In the test, participants are asked to rate the extent to which an emotion is expressed by the semantics alone (semantic-rating task), the prosody alone (prosodic-rating task), or the sentence as a whole (general-rating task).

Tinnitus-related effects: identification of semantics and prosodic emotional cues

Based on the literature presented above, it is possible that tinnitus may affect correct identification of semantic cues and prosodic cues (mainly due to sensory changes). To ensure that differences in processing emotional cues, if found, are not partially due to difficulties in inhibiting the information conveyed by the irrelevant channel, we test a baseline condition (where one channel conveys a neutral emotion). For example, we test whether PwT correctly perceive the happy emotional semantic content of the sentence "I won the Lottery today" when it is spoken with neutral prosody. A group difference in this measure, if found, would suggest that tinnitus impairs the processing of emotions in the prosodic or semantic channel, already on the perceptual level.

Tinnitus-related effects: failures of selective attention

The literature points to a possible decrease in the ability to inhibit irrelevant information for PwT. Thus, we expect that when *competing* information is conveyed by the irrelevant auditory channel, we will find larger failures of selective attention in PwT as compared to PnT. Notably, as previous results have been inconclusive regarding the effect of tinnitus on selective attention when using auditory stimuli, it is possible that increased selective attention failures will not be found for PwT. This is tested directly when listeners are asked to rate the emotions presented in one channel (e.g., semantics), while ignoring the other channel (prosody) that conveys a different emotion (semantic- and prosodic-rating task of mismatched sentences). Take for example the semantically happy sentence "I feel wonderful today" spoken with angry prosody. When asked to focus on the semantic content, are PwT able to ignore the prosody to the same extent as their PnT peers? Group differences would suggest a more central, attention-based source, for difficulties that PwT experience in spoken communication.

Tinnitus-related effects: integration of channels

A recent study conducted in the population of older adults (Ben-David et al. 2019) found that aging-related differences in the perception of emotions in speech were not generated by misidentification of either one of the channels, or by failures of selective attention. Differences were rather engendered by assigning different weights to the two channels. Namely, whereas younger adults were biased to the prosody, older adults assigned more weight to the semantics. It is possible that PwT and PnT will assign weights to the semantic and prosodic channels differently. This is tested directly in the prosodic dominance measure. Return to the semantically happy sentence "I feel wonderful today" spoken with angry prosody. When asked to rate the emotion expressed by the speaker based on both channels (the spoken sentence as a whole), are PwT biased towards the (angry) prosody to the same extent as their PnT peers? If not, this would suggest that PwT are processing the spoken emotions differently than PnT.

Method

Participants

The tinnitus group (PwT) consisted of 22 participants, 14 men and 8 women, average age 41.5 years (SD: 10.3, range: 27–56), who have been diagnosed with tinnitus for at least three months. All participants in the PwT group were enrolled at the Ear Nose and Throat (ENT) outpatient clinics of the Wolfson Medical Centre (located in central Israel, serving over 20,000 patients per year). All PwT participants provided a recent (less than 3 months) pure-tone audiometric threshold test and a medical assessment by an ENT specialist (all were conducted at the medical centre). Twenty-four PnT controls were recruited to the study via ads published at the medical centre. The control group consisted of 7 men and 17 women, average age 38.5 years (SD: 6.2, range: 28–47). Note, of the original recruited groups of participants, three PwT and one PnT were excluded from the study, either because their scores on the WAIS vocabulary subtest were below 7, the expected norm for native Hebrew speakers (Wechsler 2008), or because they failed to complete the experiment.

Participants in both groups were asked to report on possible tinnitus and other auditory problems. All participants in the control group reported good hearing and no history of tinnitus. For both groups, we excluded from the study (as specified in our advertisements) participants younger than 18 and older than 56 years of age, to avoid the effects of older age (Ben-David et al. 2019). We also excluded patients who suffer from any health-related diagnosis other than tinnitus, to avoid co-morbidity. Participants in both groups were native Hebrew speakers, as assessed by a self-assessment questionnaire and by the vocabulary subtest of the Wechsler Intelligence test in Hebrew (Wechsler 2008) scoring at least 7. We also ensured that all participants had normal to moderate affective symptoms (stress, anxiety and depression) by using the DASS-21 self-report (Henry

Table 1. Demographic information and individual scores on audiometric thresholds, personality assessment and vocabulary scale for the PwT group.

Participant	Age (years)	Gender	Education	Vocabulary Z-score (WAIS)	PTA (dB HL) Right ear	Left ear	TFI scores	DASS-21 Stress	Anxiety	Depression
101	52	F	Academic	10	15	10	46	14	10	10
102	35	M	H school	10	10	5	74	14	8	10
104	45	M	Academic	12	5	10	19	10	6	6
105	46	F	H school	7	15	15	77	16	14	10
106	32	M	H school	12	20	20	45	12	8	8
108	27	F	H school	16	20	25	16	10	8	8
109	35	M	Academic	10	10	10	43	18	8	8
110	55	M	H school	8	10	5	52	12	8	6
111	56	M	Academic	10	5	5	30	14	10	14
112	38	M	Academic	9	20	20	49	16	8	8
113	34	F	H school	7	25	25	76	8	12	6
114	51	F	Academic	11	35	35	84	18	10	20
115	51	F	H school	10	15	15	43	20	14	12
116	52	M	Academic	11	15	25	65	16	14	10
117	28	M	Academic	14	15	20	67	18	12	16
118	51	F	H school	9	20	20	15	8	6	12
119	54	M	H school	8	35	35	62	12	8	10
121	43	F	H school	9	10	5	55	18	6	12
122	31	M	Academic	14	15	20	26	14	12	10
124	27	M	Academic	15	10	10	26	8	6	6
126	43	M	Academic	10	15	15	29	12	8	8
127	28	M	H school	14	5	5	23	16	8	14

Vocabulary (WAIS) – Z score of 7 and above is taken to represent native Hebrew speaker's ability. DASS – For the Anxiety scale, scores lower than 19 reflect normal to mild anxiety, 19–25 – moderate stress and score over 25 – severe and extremely severe stress. Education, H school = high school diploma, Academic = at least obtained a bachelors at an accredited academic institute. TFI score – The scale reflects the severity of the tinnitus, 1 = not a problem, 2 = small problem, 3 = moderate problem.

and Crawford 2005), with scores lower than 25. Information about the level of education was also obtained from all participants. All participants have received a monetary compensation (about $10) for their participation. The study was approved by the respective ethics committees at the medical centre and at the academic institute. For the full demographic data and individual scores on audiometric thresholds, personality assessment and vocabulary, see Table 1 for PwT and Table 2 for PnT.

The two groups were matched on age ($t(44) = 1.2$, $p = 0.23$), on vocabulary scores ($t(44) = 1.04$, $p = 0.3$) and academic education ($\chi^2(1) = 1.32$, $p = 0.25$). However, the PwT scored lower on audiometric pure tone thresholds (PTA for the better ear; 15.2 versus 6.7 dB HL, $t(44) = 4.3$, $p < 0.001$), higher on affective symptoms (combined DASS-21 score 34.7 versus 29; $t(44) = 2.8$, $p = 0.008$) and the two groups differed in respect to gender proportion ($\chi^2(1,46) = 5.5$, $p < 0.05$, 36.4% versus 70.8% women for PwT and controls, respectively).

All participants in the PwT group were asked to complete the Hebrew adaptation of the Tinnitus Functional Index (TFI: Oron et al. 2018; for more details on TFI, see Meikle et al. 2012) indicating the effect of tinnitus on daily activities. The TFI scores in the PwT group varied from 15.2 to 84 ($M = 46.4$, SD = 21.7). We verified that the TFI scores were correlated with the DASS scores, as expected from the literature, $r_p(23) = 0.41$, $p = 0.005$, where DASS scores increase as tinnitus complaints rise (see Crocetti et al. 2009; Weber, Jagsch, and Hallas 2008).

To ensure that the effects of tinnitus on the tested variables do not stem from differences in the above stated demographic variables, we included PTA (on the better ear) and gender as between-participant variables in designated ANOVAS. Given the variance in TFI, this factor will be tested separately in the data analysis. In follow-up analyses, we divide the PwT group into two subgroups based on TFI score: low-medium complaints ($n = 8$, 6 males, M age = 38.5 years, TFI <42), and moderate-severe complaints ($n = 14$, 8 males, M age = 43.4 years, TFI > 42), following findings from the literature (Carpenter-Thompson et al. 2015). Age and gender did not differ significantly between groups, $t(20) = 1$, $p = 0.3$, and $\chi^2(1) = 0.7$, $p = 0.4$, respectively.

Tools and materials

Test of rating of emotions in speech (T-RES)

T-RES stimuli. In this test, participants are presented with spoken sentences in which the emotional semantic and prosodic content appear in different combinations from trial to trial. For example, consider Figure 1. The cell that is marked as A, a matched stimulus, represents a semantically happy sentence (e.g. "Congratulations, you are hired") spoken with happy (matched) prosody. The cell marked as B, a mismatched stimulus, represents a semantically happy sentence (e.g. "You have got first place") spoken with angry (mismatched) prosody. The cell marked with C, a baseline for semantic channel, represents a semantically happy sentence ("This is my favourite part") spoken with neutral (emotionless) prosody, whereas the cell marked with D, a baseline for the prosodic channel, represents a semantically neutral sentence (e.g., "Red pipes are metallic") spoken with happy prosody. We used the Hebrew version of the T-RES (Shakuf et al. 2016), with the following emotions: Anger, Happiness, Sadness and Neutral. To avoid possible biases (Larsen, Mercer, and Balota 2006), semantic sentences were equated on main linguistic characteristics (e.g. frequency of usage, sentence length) across the four affective categories (for detailed method, see (Ben-David et al. 2011). These sentences were recorded by a native Hebrew Israeli professional radio-drama actress, using the four different prosodies. The final experimental set was made of two subsets of 15 sentences, where each semantic category was represented once in each of the tested prosodies, generating a 4 (semantic) × 4 (prosody) matrix, as shown in Figure 1. Note, the combination of neutral prosody and neutral semantics was deemed uninformative (see Ben-David et al. 2016) and removed. All sentences were rated as distinctive and exemplars of their respective semantic and prosodic

Table 2. Demographic information and individual scores on audiometric thresholds, personality assessment and vocabulary scale for the control group.

Participant	Age (years)	Gender	Education	Vocabulary *Z*-score (WAIS)	PTA (dB HL)		DASS -21		
					Right ear	Left ear	Stress	Anxiety	Depression
201	28	F	H school	11	10	5	14	10	10
203	34	F	Academic	12	5	5	8	10	8
204	35	M	Academic	10	10	10	14	8	10
205	46	F	Academic	8	10	5	14	6	6
207	43	M	Academic	13	15	5	10	6	8
208	37	F	Academic	11	5	5	8	6	6
209	33	F	H school	12	10	15	10	6	8
210	38	F	Academic	11	10	10	8	6	10
211	33	F	Academic	15	5	5	20	8	12
212	30	F	Academic	13	5	10	10	6	8
213	45	F	H school	9	5	5	14	8	12
214	47	F	Academic	9	10	10	6	6	8
215	38	M	H school	13	10	15	16	10	6
216	39	F	Academic	9	5	15	10	6	8
217	46	F	Academic	10	5	5	8	6	8
218	34	F	Academic	11	10	5	16	6	8
219	31	F	Academic	14	15	5	20	12	10
220	44	M	Academic	14	10	15	10	6	8
221	39	M	Academic	15	10	5	20	8	10
222	45	M	Academic	13	5	5	6	6	6
223	29	F	H school	10	10	10	10	6	8
224	39	F	H school	8	10	15	8	8	8
225	47	F	H school	9	5	10	12	6	10
226	45	M	H school	9	5	5	6	2	10

Vocabulary (WAIS) – Z score of 7 and above is taken to represent native Hebrew speaker's ability. DASS – For the Anxiety scale, scores lower than 19 reflect normal to mild anxiety, 19–25—moderate stress and score over 25—severe and extremely severe stress. Education, H school = high school diploma, academic = at least obtained a bachelors at an accredited academic institute.

categories by a group of trained raters (following the procedures discussed in (Ben David et al. 2011; Ben-David et al. 2013). Digital audio files were equated with respect to their root-mean-square amplitude and duration.

T-RES design. On each trial, listeners are asked to rate how much they agree that the speaker conveys a predefined emotion (anger, sadness or happiness, in three separate rating-blocks), using a six-point Likert scale. For example, "How much do you agree that the speaker is happy? From 1—strongly disagree to 6—strongly agree". The three emotions included in the T-RES are known to be expressed universally (Zupan et al. 2009), easily recognised and distinguished in both semantics and prosody (Laukka 2006; Scherer, Banse, and Wallbott 2001). The test also includes a neutral category as a baseline condition for performance, resulting in four emotions presented across the semantic and prosodic channels, as presented in Figure 1.

T-RES tasks. The T-RES consists of three tasks: (a) Semantic rating, where listeners are asked to rate the sentence based only on semantic information; (b) Prosodic rating, where listeners are asked to rate the sentence based only on prosodic information; (c) General rating, where listeners are asked to rate the overall emotion of the sentence as a whole. Performance on these tasks will be used to answer the three research questions posed in this study, assessing differences between the PwT and PnT groups. (1) *Identification of emotional semantic content* will be assessed by analysing semantic-ratings for baseline sentences (as presented in cell C in Figure 1), where all sentences are spoken with neutral emotional prosody. (2) *Selective attention* to one of the auditory channels will be gauged in the Semantic-rating and Prosodic-rating tasks, by assessing the mismatched sentences (black cells in Figure 1)—presenting different emotions in the semantic and prosodic channels. Note, here listeners are asked to actively ignore the emotional content of one channel (to-be-ignored channel) while focussing on the other (target channel). (3) *Prosodic dominance:* the differences in the relative weights of prosody and semantic content, will be estimated in the General-rating tasks[a].

Design and procedure

Upon arrival, all participants received a short explanation regarding the experimental task, and signed an informed consent form. Next, tinnitus status, socio-demographic status and audiometric thresholds were obtained. All participants were tested individually, in a double-door sound attenuated chamber at the ENT out-patient clinics at the medical centre. Spoken sentences were routed through an HP Pavilion g6 laptop to the GSI clinical audiometer 61 and then to two stereo speakers located inside the chamber. Sound was presented at a level of 70 dB SPL, as tested (and adjusted) using a TES 1350 A sound level metre placed at the listener's location in the booth (averaged across ten stimuli).

Participants were asked to rate how much they agree that the speaker conveys a predefined emotion, in three separate emotion-rating blocks (anger rating, sadness rating or happiness rating), using a six-point Likert scale, in each of the three tasks, Semantic, Prosodic and General rating. Each rating block commenced by two practice trials, followed by a reminder of the instructions. Participants initiated the experimental trials by a key press. Each trial began with the presentation of an audio file containing one of the spoken sentences, followed by the specific instructions presented on the monitor. As the T-RES gauges the listener's subjective perception of emotion, no feedback was provided throughout the task (i.e., there are no "right" or "wrong" answers).

The experimental session started with the General-rating task, to prevent biasing the listeners to pay attention to a specific

[a]Note, the original T-RES included the fear emotion as well. However, to shorten the test, we removed this emotion, as it was found to be the least reliable in a previous study (Ben-David et al., 2016).

channel. For a randomly selected half of the participants, this was followed by the Semantic-rating task and then the Prosodic-rating task. For the other half, this order was reversed. The order of the three emotion-rating blocks was counterbalanced by using the Latin square design. In each of the rating blocks, all 15 sentences in a subset were presented (presenting all combinations of emotions across semantics and prosody), and the order of the trials in each block was fully randomised (closely following the original T-RES study, see Table 2 in Ben-David et al. 2016). To increase the test's reliability, the spoken sentence was presented once on a trial, and participants were not given the option to replay it. In addition, each sentence was presented three times in each task, once in each of three rating blocks (anger rating, sadness rating and happiness rating), with a total of 135 trials per session (less than 25 min).

Finally, participants were tested on the vocabulary subtest of the WAIS IV (Wechsler 2008), followed by two self-report questionnaires: DASS-21 (Henry and Crawford 2005), and the TFI (Oron et al. 2018). At the end of the experimental session, all participants were debriefed about the research objectives along with a brief background description and were compensated for their time.

Statistical analyses

All of the following analyses used mixed-model 2×3 repeated-measures mixed-model ANOVAs (GLM) with average ratings as the dependent variable, group (2: PwT vs. PnT) as a between-participant variable and target emotion (3: anger, sadness or happiness) as a within-participant variable. Each test included one other within-participant variable, as specified in Appendix 1. As gender and PTA appear to differ between the two groups, these factors were included in all ANOVAs as between-participant variables. As they did not yield any significant effects in the separate ANOVAs they will not be discussed in each analysis. Partial eta squared (η_p^2) was used as the measure for power in all statistically significant tests.

Results

Identifications of emotions: can both groups correctly identify emotions presented in the prosodic and lexical channels, separately?

First, we verified that both PwT and PnT were able to correctly identify emotions in the semantic and prosodic channels, in the Semantic- and Prosodic-rating tasks, respectively. We tested baseline sentences, where the to-be-ignored channel is neutral (denoted as white cells in Figure 1). We tested the difference between the average ratings of sentences that present the target emotion in the attended channel versus sentences that do not (emotion identification, see Equation (1) in Supplementary Appendix 1). For example, the prosodic ratings for anger of a semantically neutral sentence "The earth is round" spoken with angry prosody should be very high, as the prosody (target channel) conveys the target emotion (target emotion present). In contrast, the average prosodic ratings for anger of semantically neutral sentences spoken with non-angry prosody (sad and happy), should be very low, as the prosody (target channel) does not convey the target emotion (target-emotion absent). Indeed, the expected results are found in an average across both groups, with $M = 5.6/6$, $SE = 0.3$ and $M = 2.29/6$ SE = 0.24, for prosodic anger—present and absent sentences, respectively.

We conducted a repeated-measures mixed-model ANOVA with emotion identification (target emotion present versus absent), target channel (semantic- versus prosodic rating) and target emotion (anger, happy or sad), as within-participants variables and group membership (PwT and PnT), gender and PTA as between-participants variables. Analysis across target emotions, target channels and group membership statistically confirmed the trend presented above. A significant main effect for emotion identification was found, $F(1,37) = 244.1$, $p < 0.001$, $\eta_p^2 = 0.87$, with target emotion present trials ($M = 5.38/6$, $SE = 0.1$) rated significantly higher than target emotion absent trials ($M = 2.04/6$, $SE = 0.16$). This effect indicates that, in general, listeners were able to easily identify the presented emotion. No significant main effect was found for group membership, $F(1,37) = 0.98$, $p = 0.33$. Emotion-identification interacted significantly with target channel, $F(1,37) = 4.86$, $p = 0.03$, $\eta_p^2 = 0.12$, with a larger extent for semantic ratings than for prosodic ratings. That is, in semantics ratings, the difference between target-emotion present and absent sentences was larger than in prosodic-ratings (semantics rating: mean difference = 3.7; prosodic rating: mean difference = 3.0). This difference did not significantly interact with group membership.

To answer our first research question, emotion-identification did not interact with group-membership, $F(1,37) = 0.16$, $p = 0.69$, nor did we find a triple interaction of emotion-identification, group-membership and target channel, $F(1,37) = 1.88$, $p = 0.18$. Thus, groups did not differ significantly in identifying emotions in either channels. In addition, it appears that both groups were able to successfully perform the task and identify emotions in both the lexical and prosodic channels, according to tasks' instructions. Moreover, for both groups, the extent of semantic ratings was higher than prosodic ratings.

Selective attention: is there a difference in selective attention to the prosodic or the lexical channel, between PwT and PnT groups?

Here, we compared the extent of failures to selectively attend to one of the auditory channels, while ignoring the other, between the PwT and PnT groups. We compared the difference between average ratings of sentences that present the target emotion *only* in the to-be-ignored channel, and sentences that do not present the target emotion in either channel (Equation (2) in Supplementary Appendix 1). If listeners can selectively attend to one channel, this difference should be zero. If they cannot, this difference gauges the extent of failures of selective attention. For example, if a listener can fully selectively attend to the semantics, then anger semantic ratings of a semantically non-angry sentence "I really love nature" spoken with angry prosody should be minimal, as no anger (target emotion) is presented in the semantics (target-channel). Similarly, anger prosodic ratings of a non-angry sentence "I won the Lottery" spoken with non-angry prosody should be equally minimal. In both cases, semantic anger is not present, thus semantic ratings for anger should not differ between the two. Yet, if listeners cannot ignore the prosodic anger, significant differences ensue.

We conducted a repeated-measures mixed-model ANOVA with selective attention (target emotion present or absent in the to-be-ignored channel), target channel (semantic- versus prosodic rating) and target emotion (anger, happy or sad) as within-participants variables, and group membership (PwT or PnT), PTA (of the best ear) and gender as between-participant variables.

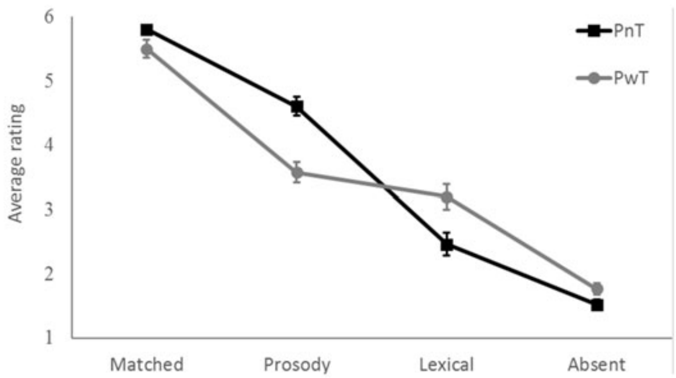


Figure 2. Graphic description of ratings in the general-rating task for PwT (gray line) and PnT (black line). Ratings are averaged for target emotion-matched trials (the target emotion appears in both channels), target emotion-prosody trials (the target emotion appears only in the prosody); target emotion semantics trials (the target emotion appears only in the semantics); and target emotion absent trials (the target emotion does not appear in either the semantics or the prosody). Error bars represent standard errors.

Results show a significant main effect for selective attention, indicating failures of selective attention for both groups across all emotions, $F(1,37)= 12.6$, $p = 0.001$, $\eta_p^2 = 0.25$. No significant main effect for group membership was found, $F(1,37) = 0.46$, $p = 0.5$, nor a significant interaction between the two factors, $F(1,37) = 0.56$, $p = 0.46$. In addition, no significant interaction of selective attention with target-channel factor was found, $F(1,37) = 0.08$, $p = 0.78$, and no triple interaction of selective attention, target channel and group membership was found, $F(1,37) = 0.96$, $p = 0.33$.

In addition, to answer our second research question, both groups performed with a similar degree of failures of selective attention, and the target channel did not affect these failures.

Integration of channels and channel dominance: is there a difference in the weights assigned to the semantic and prosodic channels, between PwT and PnT groups?

Figure 2 presents a graphic description of ratings in the general-rating task, averaged across the three emotion-rating blocks, separately for PwT and PnT, for target emotion-matched trials (the target emotion appears in both channels), target emotion-prosody trials (the target emotion appears only in the prosody), target emotion-semantics trials (the target emotion appears only in the semantics) and target emotion-absent trials (the target emotion does not appear in either the semantics or the prosody). Figure 2 suggests that average performance across groups mimics the linear trend observed with a non-clinical group in the original study (Ben-David et al. 2016). Target emotion-matched trials received the highest emotional ratings for both groups, followed by target emotion-prosody trials, target emotion semantics trials and finally, target emotion-absent trials. The most notable feature of the graph is the apparent group interaction: PnT-rated target emotion-prosody sentences higher than target-emotion-semantic sentences ($M = 5.19/6$, $SE = 0.27$ versus $M = 3.17/6$, $SE = 0.33$, respectively, replicating Ben-David et al.'s 2016 results), whereas this trend appears to be minimised for PwT (means of 3.94/6, SE = 0.17 versus 3.39/6, SE = .2, respectively).

These observations were supported by the mixed-model repeated-measures ANOVA, where we tested the linear trend (target emotion-matched > -prosody > -semantics > -absent trials) with target-emotion (anger, happy or sad) as within-participants variables, and group membership (PwT and PnT), PTA (best ear) and gender as a between-participant variables. The ANOVA indicated a significant linear trend across groups, $F(1,37) = 399.4$, $p < 0.001$, $\eta_p^2 = 0.92$, that interacted significantly with group, $F(1,37) = 16.8$, $p < 0.001$, $\eta_p^2 = 0.31$. We also note a main effect for group, $F(1,37) = 6.8$, $p = 0.01$, $\eta_p^2 = 0.16$, with overall slightly higher ratings provided by the PnT than the PwT group ($M = 4.00/6$, SE = 0.15 versus $M = 3.6/6$, SE = 0.09).

To clarify this interaction, follow-up analysis (replicating the ANOVA described in the Method section) tested the possible effects of age-group on the three effects identified in the original T-RES study with younger adults (Ben-David et al. 2016): (A) *Supremacy of congruency*; the extensive advantage for target emotion-matched trials over target-emotion-prosody trials was significant across groups, $F(1,37) = 58.8$, $p < 0.001$, $\eta_p^2 = 0.61$, and did not significantly interact with group, $F(1,37) = 2.8$, $p = 0.1$. (B) *Semantics* appears to play a similar role for both groups. Target-emotion-semantics trials were rated significantly higher than target emotion-absent trials, $F(1,37) = 58.1$, $p < 0.001$, $\eta_p^2 = 0.61$, to a similar extent in both groups, as this advantage did not interact significantly with group, $F(1,37) = 0.13$, $p = 0.72$. (C) The effect for *prosodic dominance* (the advantage for target-emotion-prosody over target-emotion-semantics trials) was significant when tested across groups, $F(1,37) = 7.6$, $p = 0.009$ $\eta_p^2 = 0.17$. However, in contrast to the previous results, prosodic dominance interacted significantly with group membership, $F(1,37) = 7.9$, $p = 0.008$ $\eta_p^2 = 0.18$, with a larger extent documented in the PnT group. Separate tests show that prosodic dominance was significant for PnT (4.7 versus 2.4), $F(1,21) = 49.7$, $p < 0.001$, $\eta_p^2 = 0.70$. But for PwT, prosodic dominance was not statistically significant (3.7 versus 3.4), $F(1,14) = 0.64$, $p = 0.44$. Figure 3(a–c) shows that the interaction of prosodic dominance and group is apparent and significant on all three target emotions, even if to a different extent, Anger: $F(1,37) = 4.4$, $p = 0.04$, $\eta_p^2 = 0.11$; Happy: $F(1,37) = 5.5$, $p = 0.025$, $\eta_p^2 = 0.13$; Sad: $F(1,37) = 5.4$, $p = 0.025$, $\eta_p^2 = 0.13$. Finally, we note that the source for this group-effect in prosodic dominance stems from reduced ratings provided for target emotion prosody trials by PwT, $F(1,37) = 17.6$, $p < 0.001$, $\eta_p^2 = 0.32$, while target emotion semantics trials were not significantly affected by group membership, $F(1,37) = 0.55$, $p = 0.46$.

To further validate this interaction, a separate analysis was conducted for baseline sentences, comparing semantically neutral sentences that carry the target emotion in the prosody, with prosodically neutral sentences that carry the target emotion in the semantics. Here, even when emotion integration (or possibly inhibition) was minimised, we found a significant prosodic dominance, $F(1,37) = 21.4$, $p < 0.001$, $\eta_p^2 = 0.37$, that significantly interacted with group, $F(1,37) = 5.4$, $p = 0.026$, $\eta_p^2 = 0.13$.

In addition, to answer our third research question, prosodic dominance, a marker of spoken emotion processing in PnT was not observed in PwT. In other words, tinnitus appears to impact the perception of emotions in speech by altering the weights assigned to the semantic and prosodic channels.

Individual differences

In all the analyses discussed above, we used gender and PTA (on the better ear) as between-participant variables. In none of these analyses, these variables yielded a main effect or significantly interacted with any of the reported effects. To test the effect of the extent of complaints, as measured by the TFI questionnaire, we replicated all analyses for the PwT group. The TFI grouping

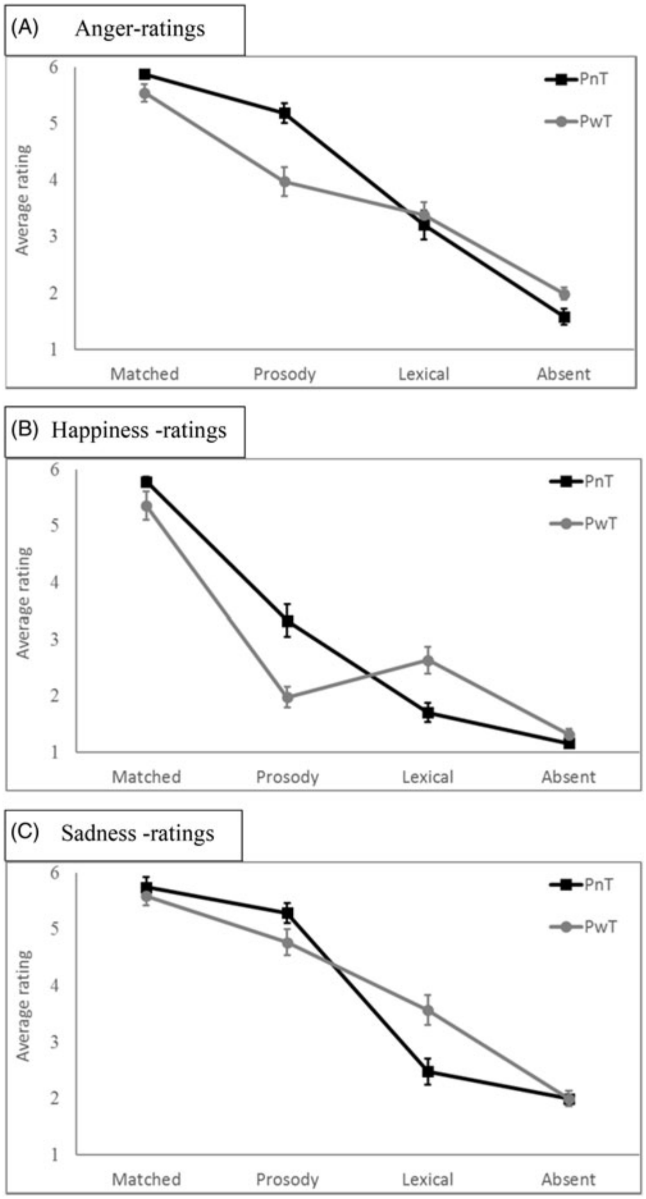


Figure 3. Graphic description of ratings in the general-rating task for PwT (gray line) and PnT (black line) in each discrete emotional rating block, Panel A: Anger rating (target emotion = anger), Panel B: Happiness rating (target emotion = happy) and Panel C: Sadness rating (target emotion = sad). Ratings are presented for target emotion-matched trials (the target emotion appears in both channels), target emotion prosody trials (the target emotion appears only in the prosody); target emotion semantics trials (the target emotion appears only in the semantics); and target emotion absent trials (the target emotion does not appear in either the semantics or the prosody). Error bars represent standard errors.

factor did not significantly interact with any of the trends reported above, nor did it generate a main effect in any of the analyses ($F < 1$ for all effects). Finally, as prosodic dominance was the sole factor for which we found a significant group effect, we generated a prosodic dominance variable—the advantage for average ratings of target-emotion-prosody trials over target-emotion-semantics trials. This variable did not correlate significantly with TFI scores for the PwT group, $r_p(22) = 0.03$, $p = 0.89$, nor did it correlate with DASS scores for the whole sample, r_p (46) $= -0.26$, $p = 0.13$.

In addition, to answer our third research question, PwT and PnT do not integrate emotions in the prosodic and semantic channel in the same manner—PnT are biased towards the prosodic content of the spoken sentence, whereas PwT weigh both channels more equally. It appears that the existence of tinnitus has a significant effect on processing of emotion in speech, but the extent of complaints related to the tinnitus did not lead to such effects. Similarly, an affective source, as tested by the DASS does not appear to have an impact as well.

Discussion

Tinnitus is a debilitating disorder causing disturbance to daily life in general and specifically impacting communication. In the current study, we focussed on the possible impact of tinnitus on the perception of emotions in speech, due to the major role emotions play in social interactions. The current study appears to be the first to examine in PwT the perception of emotions in the semantics and the prosodic channels when listening to speech. We employed a novel test, Test for Rating of Emotions in Speech (T-RES), that focuses on the interaction between emotions conveyed via the semantic (lexical content) and prosodic (tone of speech) channels. Our findings, comparing 22 adults with tinnitus (PwT) and 24 matched controls (PnT), highlight the following main trends: (1) *Identification of emotions*—both PwT and PnT were equally able to identify the emotions presented in one channel, when no competing information was presented in the other. (2) *Failure of selective attention*—ratings of both groups indicated failures of selective attention (in both channels) to a similar extent. (3) *Channel dominance*—for PnT, a large and statistically significant bias towards prosody was documented, similar to findings in the literature. However, for PwT, semantics and prosody were weighed more equally, with no statistically significant bias to either channel. Our results suggest that tinnitus may impact the perception of emotions in speech by affecting the integration of the two speech channels, semantics and prosody.

Identification of emotions

Our findings did not indicate any impact of tinnitus on identification of either semantics or prosodic cues. The literature reviewed in the outset of this manuscript suggests that PwT may have difficulties in recognising single spoken words in an utterance, especially in adverse conditions (Gilles et al. 2016; Hennig et al. 2011). This may reflect a general impairment in the identification of the semantics channel in PwT. Our data indicate that this difficulty does not affect the ability of PwT to understand the emotional content (gist meaning, central information) of a whole sentence, when it is presented in ideal listening conditions (sound attenuated booth). Similarly, the literature suggests that the tinnitus can impair the detection of the acoustic features that underlie prosodic cues (Tai and Husain 2019). In addition, to this perceptual source, a recent study suggests that tinnitus may affect emotional processing (Carpenter-Thompson et al. 2015). Namely, the authors found a relationship between tinnitus severity and brain activation during emotion processing of pleasant and unpleasant non-lexical human vocalisations (e.g. kids giggling, babies crying).

However, our data point to the resilience of PwT, at least when processing a semantically correct spoken sentence presented in ideal listening conditions. It appears that the tinnitus-related decreased acoustic processing does not impair identification of emotional semantics or prosody. Indeed, it may be that PwT take advantage of the redundancy of cues in semantics and prosody that exist in a whole sentence and may not exist in a single spoken word (on processing redundancy, see Ben-David and Algom 2009; Ben-David, Eidels, and Donkin 2014). This follows a similar trend found in a recent study with older adults, showing that age-related sensory degradation did not affect identification of emotions in speech channels, when no inhibition is called for (Ben-David et al. 2019).

Inhibition of emotional content (in the prosodic or lexical channel)

There is some evidence in the literature suggesting that PwT have difficulties in executive functions, specifically inhibition and selective attention. While the evidence supporting such difficulties is quite consistent in the visual domain (Hallam et al. 2004; Heeren et al. 2014; Stevens et al. 2007), whether or not similar difficulties exist in the auditory domain is less clear (Acrani and Pereira 2010; Jacobson et al. 1996; Shakarami et al. 2015). It was suggested that this decrease may relate to neurological changes (Araneda et al. 2015; De Ridder et al. 2011; Rauschecker et al. 2010) and to the tinnitus noises decreasing (and slowing down) available attentional resources (Banbury et al. 2001; Jackson et al. 2014). In the current study, when asked to focus on one auditory channel (semantics or prosody) and ignore the other, no differences were found between PwT and PnT. Thus, these results suggest a sparing of selective attention in the auditory domain for PwT.

It is possible that tinnitus-related decrease in selective attention in the visual domain do not necessarily predict a similar decrease in the auditory domain. Indeed, a recent study in aging by (Knight and Heinrich 2017) suggests that aging-related decrease in the visual colour-word Stroop test, the gold standard gauge for selective attention (see Ben-David and Schneider 2009, 2010), was not correlated with aging-related decrease in an auditory Stroop-like parallel test. Importantly, Knight and Heinrich also found that speech processing in noise, which may be related to speech processing in PwT (Gilles et al. 2016), was not related to the visual Stroop test. In other words, it is possible that selective attention performance, as measured by visual standard cognitive tests, is not predictive to performance in speech processing. This could be due to different inhibitory functions underlying performance in the auditory and visual domains (Shilling, Chetwynd, and Rabbitt 2002).

It is also possible that cognitive tests generate an artificial environment that may focus on differences in ability (for a discussion, see Ben-David, Malkin, and Erel 2018). These differences may not be reflected in daily activities, where several compensatory mechanisms may be at hand, such as redundancy of information, context etc. Indeed, the T-RES presents whole spoken sentences that entail context and a redundancy of semantic and prosodic emotional cues, thus it may have larger external validity than standard tests of selective attention using single words (e.g. auditory Stroop (Sommers and Danielson 1999). Finally, we acknowledge that tinnitus may have an effect on selective attention even in the auditory domain, but the T-RES is not sensitive enough to identify it. Future studies may wish to test this further in adverse listening conditions, as noted with older adults (Ben-David et al. 2011) and in people with reduced working memory (Nitsan et al. 2019).

Integration of channels—prosodic dominance

The most notable finding of this study is the significant tinnitus-related difference in the integration of the two speech channels. For our group of PnT, emotional ratings appear to be impacted mainly by the prosodic channel, with a smaller contribution of the semantics. This effect closely replicates findings in the literature in two languages with a non-clinical population (English: Ben-David et al. 2016; Hebrew: Shakuf et al. 2016). In contrast, PwT are less biased than matched controls in their weighting of channels, with no statistically significant prosodic dominance. Consider once more the example presented in the introduction, the semantically happy sentence "I feel wonderful today" spoken with angry prosody. While PnT generally perceive it as conveying mostly anger with only a modicum of happiness, PwT perceive it as expressing both anger and happiness to a similar extent. This may lead to misinterpretations of the true intention of the speaker.

Three possible sources for the tinnitus-related difference in the integration of channels are considered, sensory, cognitive and affective.

Sensory

As aforementioned, tinnitus can engender reduced processing of several acoustic cues. It is possible that this may impact the processing of prosodic cues more than the processing of the semantics of the spoken words. This decrease may not impact identification, as found in the separate prosodic-rating task, but it may still call for more processing resources in the processing of prosody. This imbalance in resource demands may lead PwT to underestimate the role of the prosodic channel (for a discussion on the possible role of auditory changes on resource allocation see the Ease of Language Understanding Model, ELU, Rönnberg, Holmer, & Rudner, 2019; Rönnberg et al. 2013). Indeed, in this task, we also found ratings of target emotion prosody trials to be reduced by tinnitus, whereas target emotion semantics trials were not significantly affected by tinnitus.

Cognitive

Prosodic dominance is the outcome of inhibition of the emotional content of the semantics, specifically when the semantic and prosodic emotional content differ. It is possible that tinnitus-related increased difficulty in selective attention documented in the literature is reflected here, when the task calls for attentional processing of both the semantics and the prosody. In other words, this increase in demand for cognitive processes may reveal the difficulties in inhibition that were not exposed when processing was devoted to one channel only, in the selective attention tasks (Wingfield 2016).

Affective

Finally, one may assume that group difference in prosodic dominance may be related to an affective source—i.e. depression, anxiety and stress (as measured by the DASS, in our study), and tinnitus complaints (as measured by the TFI, in our study). Moreover, in our study, and other studies (Aazh and Moore 2017; Bhatt, Bhattacharyya, and Lin 2017), scores on the degree of tinnitus severity/intrusiveness were found to be correlated with several measures of well-being, such as the DASS scale. However, in our data the extent of tinnitus complaints (TFI), and affective symptoms (DASS) were not related to performance on the speech perception task (T-RES). This leads us to believe that the differences in the processing of emotions in speech, documented in the current study, were related to the existence of tinnitus, but not to the extent of tinnitus complaints and/or affective symptoms. In other words, it appears that the effect of tinnitus on performance is not likely related to an affective source.

Summary and future directions

To date, there is no specific treatment to tinnitus (Zenner et al. 2017), thus this study focuses on the impact of tinnitus on daily activity—communication. The processing of emotions in spoken communication appears to be an understudied topic in tinnitus research. The current study is the first to test the effect of tinnitus on the perception of emotions in speech, focussing on the semantics channel, prosodic channel and their integration. Our results show that even though acoustic processing may be impaired due to the tinnitus, this does not affect the identification of the emotional content of a single channel (semantics or prosody), at least when a spoken sentence is presented in ideal listening conditions. PwT also show resilience in their ability to selectively attend to one channel while ignoring the other. However, we suggest that the source for difficulties in social interactions in PwT, as found in previous studies, may be the result of tinnitus-related differences in the integration of the two channels. Namely, while PnT are biased to prosodic emotions, PwT weigh both prosody and semantics equally. This finding may be used in therapy to promote better quality of life for PwT through social interactions.

Future studies could examine the effect of tinnitus on the perception of emotion in speech in acoustic environments which contain background noise or competing talkers, which resemble common daily environments. Noise might be also used to equate recognition accuracy of a single word between groups, by tailoring SNRs (see, Ben-David et al. 2011, 2019), to compensate for the possible effect of tinnitus-related sensory degradation in the perception of emotions in speech. We also suggest adding a working-memory load task (e.g. memorising four digits, Hadar et al. 2016), to be conducted in tandem with the T-RES task, to examine the interaction of cognitive and sensory factors, affecting speech perception in tinnitus. Such studies could further contribute to our understanding of PwT's difficulties and provide ecologically valid information as to their ability to perceive emotion in less favourable listening conditions. In addition, this study further demonstrates that the T-RES paradigm can be used with different populations. Future studies can use this paradigm to test processes underlying the perception of emotion in speech in other populations for whom emotion processing deficits have been identified, such as cochlear implant users, and other auditory pathologies.

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Declaration of interest

The authors declare that they have no conflict of interest and no interest to declare.

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