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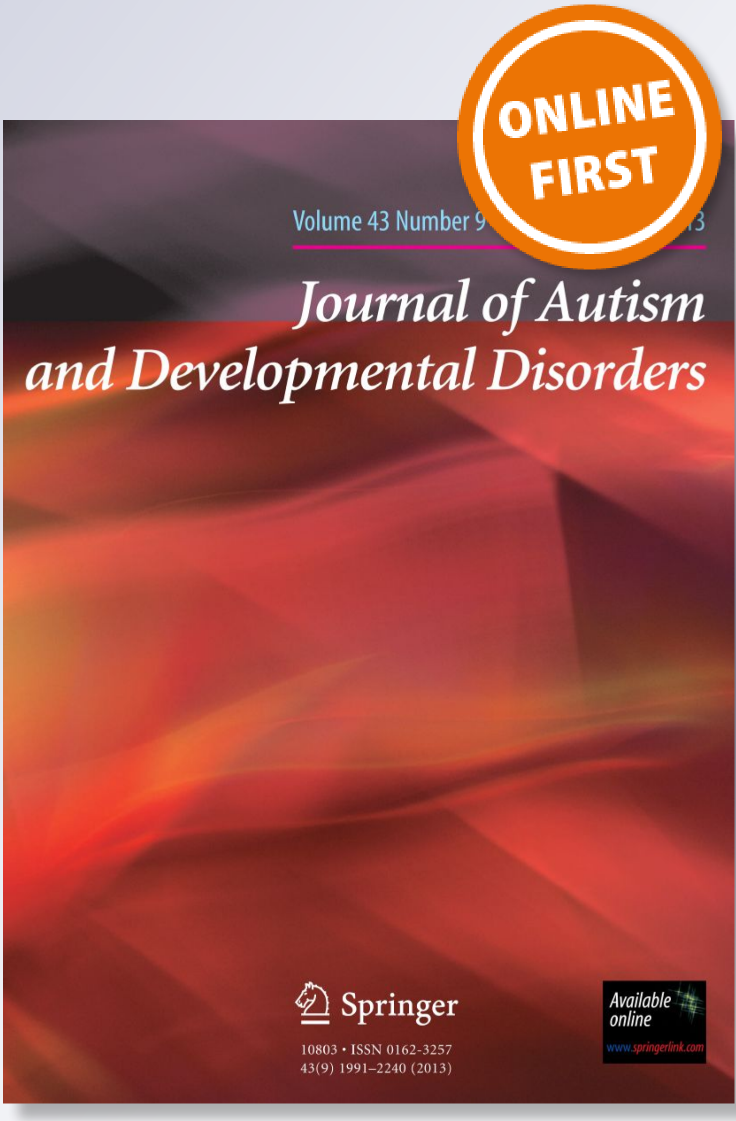

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ORIGINAL PAPER

The Perception of Emotions in Spoken Language in Undergraduates with High Functioning Autism Spectrum Disorder: A Preserved Social Skill

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Abstract

Identifying emotions in speech is based on the interaction of lexical content and prosody. This may be disrupted in individuals with High-Functioning Autism Spectrum Disorder (HF-ASD). Undergraduates with HF-ASD ($n=20$) and matched typically developed peers ($n=20$) were tested using the (Hebrew) Test for Rating of Emotions in Speech. Participants rated the degree to which a target-emotion is present in spoken sentences, in which the emotional-lexical and -prosodic content appear in different combinations from trial to trial. No group differences were found in measures of emotion-identification, selective-attention (focusing on one target-channel) and integration. These preserved abilities can partially explain the high levels of independence and self-control characterizing students with HF-ASD. Support programs may rely on such skills to improve social interactions.

Keywords Emotion · Speech · Autism spectrum disorder · High-functioning ASD · Lexical content · Prosodic content

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by impairments in social communication and social interaction and restricted repetitive pattern of behaviors, interests or activities (American Psychiatric Association 2013). ASD includes a wide range of cognitive and verbal abilities, and varies in symptom severity (Anderson et al. 2007; Boucher 2012; Grzadzinski et al. 2013; Wingate et al. 2014). Difficulties in expression and recognition of emotions are core characteristics of ASD (summarized in Uljarevic and Hamilton 2013). A subgroup of individuals with ASD who show relatively intact cognitive functioning (IQ ≥ 70), executive functioning, and language abilities, are considered as having *high-functioning ASD* (HF-ASD; Baron-Cohen et al. 1999; Sanders 2009). Although this subgroup shows relatively preserved cognitive abilities, it is still characterized by impairments in social awareness and performance (Baron-Cohen et al. 1997) and is reported to have high frequency of unemployment, along with a lack of social and economic independence (Gotham et al. 2015).

In the current study, we test whether young adults with HF-ASD process spoken emotion in a similar fashion to typically developed peers. Specifically, we target the ability to identify and integrate the emotional content of the semantics (words) and prosody (tone of speech) of spoken sentences. On one hand, reduced emotional recognition could be reflected by impaired processing of spoken emotions. On the other hand, there is evidence in the literature to suggest intact processing of spoken emotions in this population. This might be related to the general prominence of spoken

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emotions or to the preserved cognitive and verbal abilities of HF-ASD population. As post-secondary education is a good predictor for positive outcomes in adults in the general population, as well as among those with ASD (Newman et al. 2011), the current study focuses on the unique group of University undergraduates with HF-ASD and their peers.

The last two decades are marked with an attempt to increase accessibility for individuals with HF-ASD in post-secondary institutions (Brown 2012). Higher education is considered an essential step in helping young adults with HF-ASD meet their aspirations and fulfill their potential. It can serve as a path into independent and productive lives, employment and better integration into the general society. Although only a minority of cognitively abled young adults with ASD have a university education (14%, Helles et al. 2016; 17.4%, Newman et al. 2011), the numbers of enrolled students with HF-ASD are constantly rising (Raue and Lewis 2011). Yet, students with ASD reported social difficulties and a sense of loneliness in their campus experience (Gelbar et al. 2014; Jackson et al. 2018).

Successful socialization of students with HF-ASD in college campuses highly depends on their spoken communication abilities. Spoken communication, and specifically, the processing of emotions in spoken language, has an important role in daily interactions (Ben-David et al. 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 wellbeing (Hudepohl et al. 2015). Given the important role of processing emotions in speech, assessing the strengths and weaknesses of HF-ASD students regarding this function can provide an explanation for difficulties in social relationships, and offer possible routes for rehabilitation (Kouo and Egel 2016; Lindner and Rosen 2006). In order to assess this, one must first understand how spoken emotions are processed by listeners, and the possible differences in this complex ability between HF-ASD and typically developed adults.

The perception of spoken emotions involves several channels, including visual and auditory. Many studies have been focused on emotions identification in facial expressions in HF-ASD (e.g., Jones et al. 2011). Less attention has been given to the processing of the *auditory* channels in this population. In spoken language, two auditory channels express emotion—the lexical channel (semantics—the meaning of the words) and the prosodic channel (intonation of voice, indexical cues). In the absence of visual cues (e.g., during a phone call), or when visual information is degraded, these auditory channels form the main sources of information.

The literature is inconsistent regarding processing of emotions in speech (auditory modality) by individuals with HF-ASD (for a review of relevant studies in ASD, see Ploog et al. 2014). Specifically, no study has examined the ability of individuals with HF-ASD to process prosody and lexical content in the same stimulus, their ability to selectively attend to one channel while inhibiting the other, or the ability to integrate the two channels.

The goal of the current study is to compare students with HF-ASD and their typically developed (TD) peers on: (1) identification of emotions in the prosodic and lexical channel (separately) of the same stimulus, (2) selective attention to one channel, while inhibiting the other, and (3) integration of the emotional content in the prosodic and lexical channel of a spoken sentence.

The Identification of Spoken Emotions in HF-ASD

Several studies indicate difficulties in identifying emotions via prosody. Few studies reported children with HF-ASD (diagnosed with Asperger syndrome) to be less accurate in recognition of prosodic emotions than their TD peers, however, lexical content was not affected by HF-ASD (Kleinman et al. 2001; Lindner and Rosen 2006; Rutherford et al. 2002). Others added that the significant deficits in the identification of prosodic emotions for the HF-ASD group correlated with impaired social judgments (see also: Charbonneau et al. 2013; Doi et al. 2013; Globerson et al. 2015; Philip et al. 2010; Stewart et al. 2013).

In contrast, other studies did not find such prosody identification deficiency in HF-ASD. For example, Loveland et al. (1997) did not find a difference between individuals with HF-ASD and TD controls in the identification of emotions in video clips (expressing emotions in lexical content, prosody and facial expression; for similar results, see O'Connor 2007). Loveland et al. (1997) concluded that the relatively preserved cognitive abilities of HF-ASD might compensate for ASD-related challenges in emotional interpretation. Loveland and her colleagues further suggested that cognitive abilities can serve as a better marker for difficulties in identification of emotions than ASD.

Much less is known about the identification of spoken *lexical* emotions (the auditory modality) in this population, as to date no study (to the best of our knowledge) has directly tested this ability. In the visual modality, the identification of emotions in written texts has been tested. Adolescents with HF-ASD frequently show well developed word-recognition abilities and high word-reading skills. However, although they are considered to be "fluent decoders" (Senokossoff 2016), frequently they have difficulty with reading comprehension skills (Nation et al. 2006), such as making inferences, thinking critically, and taking on multiple perspectives or points of view (Randi et al. 2010). Specifically, in a story setting task, HF-ASD individuals showed difficulties in comprehension of the characters' social experiences and how these contribute to the development of motivations and actions in the story (context processing; Gately 2008).

The Processing of Emotions in Speech in HF-ASD

As noted above, the focus of previous studies was mainly on emotion identification in a single auditory channel (prosody or lexical content, separately). This limited focus on prosody, ignoring the role of channel-integration, may explain the inconsistent findings in the literature.

In daily conversations, prosody and lexical emotional content are expressed in tandem. To illustrate, imagine an undergraduate with HF-ASD receiving a phone call from a classmate saying "I feel wonderful today" spoken with an angry prosody. Such a conflicting message may be interpreted in different manners. Is the classmate expressing happiness, anger, or a combination of the two? Phrasing the above question more generally, do undergraduates with HF-ASD differ from their TD peers in the way they assign weights to the two speech channels? Can they successfully inhibit (ignore) the irrelevant channel when social norms (or the tasks) call for it? To the best of our knowledge, no study to date has addressed these issues. However, there is some indication in the literature on possible HF-ASD-related differences in *inhibition* and *integration* in non-speech domains. In the next sections, we try to infer from these evidence on the perception of emotions in speech in adults with HF-ASD.

Inhibition

Inhibition of irrelevant information is a central cognitive ability in daily life. For example, when driving a car one must attend to the road and related traffic sounds, while ignoring irrelevant visual and auditory distractors, such as billboards and music played on the radio (for a discussion, see Ben-David et al. 2018). As individuals with HF-ASD are characterized with relatively intact cognitive abilities, it is not surprising to find studies reporting that performance on inhibition/selective attention tasks are not affected in this population (or even in ASD, see Hill 2004). For example, when performing a Stroop task (the gold standard of inhibition, across populations; see Ben-David and Schneider 2009, 2010), individuals with HF-ASD and TD show equal amounts of interference when the task calls for it (incongruent trials; Panerai et al. 2014). Indeed, Schwean and Montgomery (2015) posited that inhibitory abilities may be preserved for many individuals with HF-ASD. The authors reported that even though their group of HF-ASD scored lower than the TD control group on inhibitory functions (e.g., in a Stroop task), their performance was within the norms for their age. When inhibition of emotional content was tested in the visual modality (e.g., see Geurts et al. 2009) no impairments were found for children with HF-ASD.

Difficulties that individuals with HF-ASD may have in focusing on one auditory channel while ignoring the other can be related to a possible deficit in inhibition unique to the auditory modality. Indeed, several studies found that performance on tasks that test inhibition in the visual modality does not necessarily correlate with similar tasks in the auditory modality, suggesting possible separate mechanisms (for a discussion, see Knight and Heinrich 2018). However, to date the pertinent literature is silent on inhibition processing in the auditory modality in HF-ASD.

A study by Geurts et al. (2009) is noteworthy in this respect, as they further did not find a decrease in efficiency of inhibition in individuals with HF-ASD in a task involving inhibition of emotions in visual facial expressions (see also, de Vries and Geurts 2012).

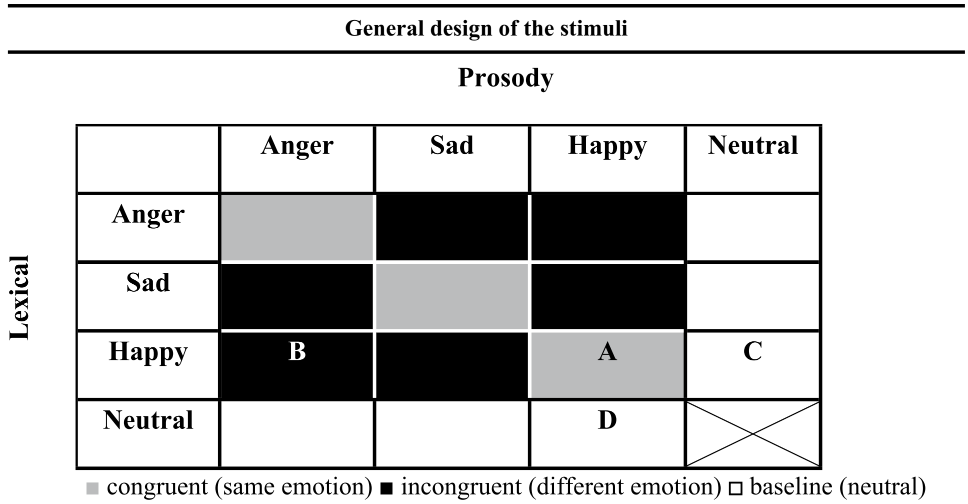
Integration

As aforementioned, processing of emotions in speech is based on the integration of the emotional content of the two auditory channels (Ben-David et al. 2016b). This demanding process may exceed the resources available for individuals with HF-ASD (e.g., Eigsti and Bennetto 2009), hampering performance. Some related evidence to support this claim can be found in a study by O'Connor (2007), in which the HF-ASD group was less accurate than the TD group in distinguishing between prosodies that matched facial expressions and those that did not. However, other studies found intact identification of prosodies in HF-ASD (e.g., in a dichotic listening task, Baker et al. 2010). So far, integration across auditory channels in general, or of prosodic and lexical content specifically, was not examined in HF-ASD.

The Test for Rating of Emotions in Speech (T-RES)

To gauge the interaction of the lexical and prosodic channels in the perception of emotions in speech, and the efficiency in inhibiting each channel, Ben-David and his colleagues developed the *Test for Rating of Emotions in Speech (T-RES,* Ben-David et al. 2016b), as depicted in Fig. 1. In the T-RES, participants are presented with spoken sentences in which the emotional lexical 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 TD young adults, Ben-David and colleagues (2016b) came to three main conclusions: (1) *Identification of emotions.* Participants successfully identified the emotions expressed in the prosody and lexical

Fig. 1 General design of the T-RES. All combinations of prosody and lexical (16) are presented in each emotional rating block (Note, neutral lexical spoken with neutral prosody was deemed uninformative and confusing, and was not presented). The shaded rows at the bottom present examples for each type of combination



Rating tasks		
General rating task	**Prosodic rating task**	**Lexical 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 lexical content.	Participants are asked to rate the sentence based only on the **lexical** 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 lexical and prosodic channels.	These tasks (resembling Stroop-like tasks) gauge age-related 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**?"

content separately; (2) *Selective attention*. Participants failed to attend selectively to one channel, while actively ignoring the other; (3) *Integration of channels: channel dominance.* Participants' ratings of sentences were affected by the emotions conveyed by both prosodic and lexical channels. Most importantly, performance indicated a "prosodic dominance" which means that prosody had a larger impact on emotional ratings than did the lexical content (see also, Mehrabian and Wiener 1967; Jacob et al. 2014).

The Current Study

The current study aims to examine the processes underlying the perception of emotions in spoken language in undergraduates with HF-ASD. This unique subgroup of individuals with ASD has recently received much interest both academically and clinically, due to its potential for integration in the general society. Performance on the T-RES was compared between two groups of students, HF-ASD and their matched TD peers. Based on the gaps in the literature, the current study aimed to answer three main research questions:

(1) *Identification of lexical and prosodic content*. Can individuals with HF-ASD correctly identify spoken lexical emotions that are not accompanied by matching prosodies? In other words, can individuals with HF-ASD correctly perceive the emotional lexical content of the spoken sentence "I won the lottery today" when it is spoken with neutral prosody? Similarly, can they correctly identify the prosodic emotion of a spoken sen-

tence that carries neutral lexical content? E.g., "there is a rug on the floor" spoken with angry prosody.

(2) *Selective attention*. Can individuals with HF-ASD inhibit one of the emotional auditory channels (prosody or lexical) as efficiently as TD individuals? That is, when listeners are specifically asked to focus on one channel (e.g., prosody) can they ignore the emotional information conveyed by the other (to-be-ignored) channel (lexical)? Take, for example, the sentence "I feel wonderful today" spoken with angry prosody. When asked to focus on the happy lexical content, are individuals with HF-ASD able to ignore the (angry) prosody to the same extent as their TD peers?

(3) *Integration of channels: prosodic dominance*. Do students with HF-ASD assign larger weight to the prosodic channel, to the same extent as TD? Return to the sentence "I feel wonderful today" spoken with angry prosody. When asked to rate the emotion expressed by the speakers based on both channels, are individuals with HF-ASD biased towards the (angry) prosody just like their TD peers?

The literature presented above may lead to two contrasting hypotheses. The evidence on reduced emotional processing in the ASD spectrum may suggest differences in the processing of spoken emotions between students with HF-ASD and their peers. Impaired identification and selective attention to spoken emotions or a non-typical integration of prosodic and lexical content would support the first hypothesis. Conversely, preserved cognitive abilities in HF-ASD, as mainly documented thus far in the visual modality, may extend to the auditory modality. Finding no significant group differences in identification, selective attention or integration of prosodic and lexical channels would support the latter hypothesis. Finally, we will discuss how our findings may assist in designing efficient rehabilitation programs for this important group.

Method

Participants

The study included 40 university undergraduates, their full background data is presented in Table 1. Of them, 20 participants had a diagnosis on the autism spectrum, as were provided by a licensed neurologist or psychiatrist (based on DSM-IV or DSM-IV-TR criteria; American Psychiatric Association 1994, 2000), with an I.Q. score and academic abilities within the normal range. Prior to the DSM-5 (American Psychiatric Association 2013), children might have been given one of three different diagnoses: autistic disorder, pervasive developmental disorder or Asperger's syndrome (American Psychiatric Association 1994, 2000). In the latest version, DSM-5, individuals with any of these disorders are grouped together under the continuum of "Autistic Spectrum Disorder" (Senokossoff 2016).

Table 1 Participants' background data

	HF-ASD	TD
N	20	20
Age: range, mean (SD), years	19–27, 22.9 (2.4)	22–29, 24.4 (1.8)
	$t(38) = 2.30$, $p = .025$[a]	
Gender (m, f)	18, 2	18, 2
Matriculation exam-verbal score: mean (SD)	83.5 (9.7)	78.3 (8.4)
	$t(33) = 1.70$, $p = .10$	
SCQ: range, mean (SD)	15–23, 15.8 (2.2)	1–13, 6.1 (3.4)
AQ: range, mean (SD)	40–49, 44.3 (3.3)	–
Symbol search: mean (SD)	9.4 (2.4)	–
Diagnosis	HF-ASD, AD, PDD	–

SCQ Social Communication Questionnaire, *AQ* The Autism-Spectrum Quotient; Symbol search- a subtest of WAIS IV; *HF-ASD* High Function Autism Spectrum, *AD* Asperger's Disorder, *PDD* Pervasive Developmental Disorder

[a]This small group-difference results from the mandatory military service (at the age of 18 for a minimum of three years) for participants in the TD group (individuals with HF-ASD are exempt from military service, and released from service through the military health system). Note, both groups come from the same age-range of young adults

All the participants in this group attended a university "integration program" that guides students with HF-ASD during their academic studies and provides counseling and tutorial services. It is important to note that all participants in the HF-ASD group met the formal academic entry requirements of their respective university departments, including a full matriculation certificate (high school diploma), meeting the same academic criteria as participants in the matched control group. Additionally, we assessed performance on the symbol search subtest of Wechsler Adult Intelligence Scale (WAIS IV; Wechsler 2008) to elicit minimal levels of social interaction and stress during the test. Their average scores were found to be within the normal range for their age. The other 20 participants were undergraduate students from the same university as the HF-ASD group and served as a matched control group (in terms of gender, ethnicity, age-range, academic status and background).

All participants in both groups were native Hebrew speakers, with clinically normal hearing (with no reported pathologies nor history of hearing disorders), and clinically normal or corrected to normal vision. This was assessed by a self-report and an interview with the research assistants, speech-language pathology students (one additional participant from the HF-ASD group was removed due to impaired hearing, and is not included in the study). In order to gauge their verbal ability, verbal matriculation scores were collected (data was missing for only 3 and 2 members of the HF-ASD and control group, respectively). Scores did not indicate any significant difference between the two groups, $t(33) = 1.7$, $p = .10$.

Even though all participants in the HF-ASD group were diagnosed by a licensed neurologist or psychiatrist (as aforementioned) diagnosis were further confirmed by obtaining a score of 32 or higher on the Autism-Spectrum Quotient (AQ; Baron-Cohen et al. 2001). Status was also confirmed using the social communication questionnaire, SCQ (Rutter et al. 2003). For the control group the SCQ was conducted, with all participants scoring below 13 (Barnard-Brak et al. 2016).

Undergraduates in the HF-ASD group were contacted by the HF-ASD integration program coordinator on campus and were offered to participate in the study. All those who agreed to participate (but for one with a hearing impairment) were included (purposive sampling). TD matched controls were recruited via ads published on campus. Of the applicants, we chose only undergraduates who most closely matched the HF-ASD group in age and gender. The study received full ethics approval from the university ethics committee, and all participant read and signed an informed consent. Participants were paid (the equivalent of) $30 for their participation. We note that a sample size of at least 11 participants in each experimental group is required to achieve power of 0.95 (G-Power; Faul et al. 2007) with a medium-small effect size ($f^2 = 0.33$—a conservative estimate based on $\eta_p^2 > 0.10$ for HF-ASD-related differences in prosodic identification, as found in Globerson et al. 2015).

Tools and Materials: Test for Rating of Emotions in Speech (T-RES)

T-RES Stimuli

In this test, participants are presented with spoken sentences in which the emotional lexical and prosodic content appear in different combinations from trial to trial. For example, consider Fig. 1. The cell that is marked as A, a congruent stimulus, represents a lexically happy sentence (e.g., "Congratulations, you are hired") spoken with a congruent happy prosody. The cell marked as B, an incongruent stimulus, represents a lexically happy sentence (e.g., "You've won first place") spoken with an incongruent angry prosody. The cell marked with C, a baseline for lexical channel, represents a lexically happy sentence ("This is my favorite part") spoken with a neutral (emotionless) prosody, whereas the cell marked with D, a baseline for the prosodic channel, represents a lexically neutral sentence (e.g., "Red pipes are metallic") spoken with happy prosody.

We used the following emotions: Anger, Happiness, Sadness and Neutral. To avoid possible biases (Larsen et al. 2006), lexical 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, in which each lexical category was represented once in each of the tested prosodies, generating a 4 (lexical) × 4 (prosody) matrix, as shown in Fig. 1. Note, the combination of neutral prosody and neutral lexical content was deemed uninformative (see Ben-David et al. 2016b) and therefore was removed. All sentences were rated as distinctive and exemplars of their respective prosodic and lexical categories by a group of trained raters (following the procedures discussed in Ben-David et al. 2011, 2013). Digital audio files were equated with respect to their root-mean-square amplitude and duration.

Reliability and Validity

We used the Hebrew version of the T-RES. Content validity (Chan 2014) has been confirmed as we tested and verified that all sentences are distinctive and exemplars of their respective prosodic and lexical categories (as aforementioned). This version of the test has been used with 80 younger and older adults in our lab (Shakuf et al. 2016; Ben-David et al. 2019). For example, expected ageing-related differences, as suggested from the pertinent literature, were confirmed by the T-RES, supporting its validity. We note that the Hebrew version has been used in our lab with various other populations: people with tinnitus (Levy et al. 2018; Oron et al. 2019), people with ADHD (Elkayam 2018) and following sleep deprivation (Ben-David et al. In preparation). Reliability was confirmed as data collected for younger adult undergraduates (control groups) is routinely compared across studies, and no significant study-related differences were found for the tested effects. For example, when comparing the data for control groups in Oron et al. (2019) and Elkayam (2018), no significant study-related differences were found ($F < 1$ for all).

T-RES Design

In each trial, listeners were 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 6-point Likert scale. For example, "How much do you agree that the speaker is happy? From 1—strongly disagree to 6—strongly agree." These emotions are expressed universally (Zupan et al. 2009), easily recognized and distinguished in both prosody and lexical content (Laukka 2003; Scherer et al. 2001) and were also found to be correctly identified by individuals with ASD (Golan et al. 2007). The test also included a neutral category as a baseline condition for performance, resulting in four emotions presented across the lexical and prosodic channels, as presented in Fig. 1.

T-RES Tasks

The T-RES consists of three tasks: (a) Prosodic-rating, in which listeners are asked to rate the sentence based only on prosodic information; (b) Lexical-rating, in which listeners are asked to rate the sentence based only on lexical information; (c) General-rating, in which listeners are asked to rate the overall emotion of the sentence as a whole. Performance on these tasks were used to answer the three research questions posed in this study, assessing differences between students with HF-ASD and TD. (1) *Identification of lexical content* was assessed by analyzing lexical-ratings for baseline sentences (as presented in cell C in Fig. 1), in which all sentences are spoken with neutral emotional prosody. (2) *Selective attention* to one of the auditory channels were gauged in the Lexical-rating and Prosodic-rating Tasks, by assessing the incongruent sentences (black cells in Fig. 1)—presenting different emotions in the prosody and the lexical channels. Note, in this condition listeners were asked to actively ignore the emotional content of one channel ('to-be-ignored channel') while focusing on the other ('target-channel'). (3) *Integration of channels: prosodic dominance*, or the differences in the relative weights of prosody and lexical content, was estimated using the General-rating Tasks (Fig. 1).[1] The T-RES uses a rating scale rather than a forced-choice response. Previous research (Ben-David et al. 2019) found this method to be especially adapt in uncovering (even small) differences in the subjective perception of emotional prosody and semantics between two groups, rather than merely detecting differences in emotion classification.

Design and Procedure

Upon arrival, all participants received a short explanation regarding the experimental task, and signed an informed consent form. Participants were tested individually, in a quiet room at the university lab. Instructions were presented on a 17-in. flat color monitor. Spoken sentences were presented via computer (Dell Optiplex GX1p) using a sampling rate of 22.05 kHz at 65 dB SPL, via WH-102 headphones. A research assistant, a speech-language pathology student, was present throughout the experimental session. Before conducting the T-RES, the relevant tests were administered to confirm inclusion criteria and group assignment.

Next, 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 6-point Likert scale, in each of the three tasks, Prosodic-, Lexical- and General- rating. Each rating block commenced with two practice trials, followed by a reminder of the instructions. Experimental trials were initiated by the participant. Each trial began with the presentation of the audio file, 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 channel. For a randomly selected half of the participants, this was followed by the Lexical-rating Task and then the Prosody-rating Task. For the other half, this order was reversed. In each task, the order of the three emotion-rating blocks was counterbalanced (using a Latin square) and the order of the trials in each block was fully randomized (closely following the original T-RES study, see Table 2 in Ben-David et al. 2016b). In sum, each sentence was presented three times in each task, once in one of three rating blocks (anger, sadness, and happiness), with a total of 135 trials per session. The total duration of the task was less than 25 min.

Statistical Analyses

Series of mixed-model repeated-measures ANOVAs (GLM) with average ratings as the dependent variable, group (2: HF-ASD vs. TD) as a between-participant variable and target-emotion (3: anger, sadness or happiness) as a within-participant variable were conducted. Each test included one other within-participant variable (2 or 1 levels), as specified in Online Appendix. In prosodic- and lexical-rating tasks, target-channel (2: prosodic- vs. lexical-rating) was also used as a between-participants variable.

We tested skewness for all of the main variables used in the three omnibus ANOVA (averaging across emotions). In none of these cases, we found a severe violation of skewness that may impede on ANOVA (taking the threshold of 1.75, Blanca et al. 2013; or the more lax threshold of 2.08, Cain et al. 2017; for a discussion on the robustness of ANOVA, see Berkovits et al. 2000).

Factors of order (3: order of emotional rating blocks, and 2: whether Lexical-rating Task was introduced before or after Prosodic-rating Task) were included as between

[1] Note, the long T-RES included the fear emotion as well. However, to shorten the test, we removed the fear emotion that was found to be the least reliable in previous studies (Ben-David et al. 2016b; Pell et al. 2009).

Table 2 Summary of ratings (Means and SDs), averaged across target-emotions, for the HF-ASD and control group, with F values of the comparison

	HF-ASD		Control		Group effects	Group X rating interaction
	Prosody	Lexical	Prosody	Lexical		
Identification (baseline sentences)						
Target-emotion-present	5.4 (.12)	5.6 (.14)	5.8 (.12)	5.3 (1.4)	$F(1,33)=1.4$, $p=.25$	
Target-emotion-absent	1.7 (.13)	2.0 (.14)	1.4 (.13)	1.8 (1.4)		
Identification: target-emotion-present versus target-emotion-absent sentences						$F(1,33)=1.2$, $p=.3$
Selective attention						
Target-emotion-present *only* in the to-be-ignored channel	2.1 (.14)	2.3 (.18)	1.74 (.14)	2.1 (.18)	$F(1,33)=1.98$, $p=.17$	
Target-emotion-absent	1.9 (.12)	1.7 (.1)	1.6 (.12)	1.61 (.1)		
Selective Attention: target-emotion-present *only* in the to-be ignored channel versus target-emotion-absent sentences						$F(1,33)=0.2$, $p=.6$
Integration						
Congruent sentence	5.59 (.12)		5.55 (.12)		$F(1,33)=0.05$, $p=.8$	
Prosodic sentences	4.59 (.19)		4.56 (.19)		$F(1,33)=0.003$, $p=.96$	
Congruent versus prosodic sentences						$F(1,33)=0.03$, $p=.9$
Lexical sentences	3.04 (.22)		2.57 (.22)		$F(1,33)=1.6$, $p=.2$	
Prosodic versus lexical sentences						$F(1,33)=0.6$, $p=.5$
Target-emotion-absent	2.0 (.11)		1.84 (.11)		$F(1,33)=0.5$, $p=.5$	
Lexical versus target-emotion–absent sentences						$F(1,33)=1.2$, $p=.3$

participants variables in all ANOVAs. As they did not yield any significant effects, they will not be further discussed. Partial eta squared (η_p^2) was used as the measure for power.

Results

Identification of Emotions: Can Both Groups Correctly Identify Emotions Presented in the Prosodic and Lexical Channels, Separately?

The description of the results of this section is portrayed in the top rows of Table 2. In the first step, we verified that both TD and HF-ASD could correctly identify emotions in the prosody and lexical content, with the Prosody- and Lexical-rating Tasks, respectively, using baseline sentences, where the to-be-ignored channel is neutral (denoted as white cells in Fig. 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 Eq. 1 in Online Appendix). For example, the prosodic ratings for anger of a lexically 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 lexically 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 were found in both groups. For the HF-ASD group, $M=5.5/6$, $SE=0.2$ and $M=1.7/6$, $SE=0.19$, for anger-present and absent sentences, respectively. For the TD group, $M=5.97/6$, $SE=0.2$ and $M=1.5/6$, $SE=0.19$.

We then conducted a $2\times2\times3\times2$ mixed model ANOVA with emotion identification (target-emotion-present vs. -absent), target-channel (prosodic- vs. lexical-rating) and target-emotion (anger, happy or sad), as within-participants variables, and group-membership (HF-ASD and TD) as a between-participants variable. Analysis, across target-emotions, target-channels and group-membership, statistically confirmed the trend presented above, with a significant main effect for emotion-identification ($M=5.55/6$, $SE=0.07$ vs $M=1.74/6$, $SE=0.09$, for target-emotion-present and -absent, respectively), $F(1,33)=826$, $p<.001$, $\eta_p^2=.96$. This effect indicates that, in general, listeners were able to easily identify the presented emotion. No significant main effect for group membership was found, $F(1,33)=1.35$, $p=.25$, nor for target-channel, $F(1,33)=1.5$, $p=.23$, meaning that HF-ASD group did not differ from TD group in lexical- and prosodic-ratings and lexical ratings did not differ from prosodic ratings. Emotion-identification interacted significantly with target-channel, $F(1,33)=9.86$, $p=.004$, $\eta_p^2=.23$, with larger differences in prosodic ratings than in lexical ratings. That is, in prosodic ratings, the difference between target-emotion-present and -absent sentences was larger than in lexical ratings (prosodic rating: *Mean difference* = 4.07; lexical rating: *Mean difference* = 3.54).

To answer our first research question, emotion identification did not interact with group-membership, $F(1,33) = 1.23$, $p = .28$, meaning that groups did not differ significantly in their ability to identify emotions in general. However, we note a triple interaction of emotion-identification, group-membership and target-channel, $F(1,33) = 6.4$, $p = .017$, $\eta_p^2 = .16$. Follow up analyses, separate for each group, indicate that there was a significant main effect for emotion-identification in both prosodic and lexical channels for both the HF-ASD and the TD groups, $F(1,14) > 250$, $p < 0.001$, for all comparisons. Yet, for the TD group, emotion-identification in the prosodic channel was higher than in the lexical channel, $F(1,14) = 42.0$, $p < .001$, $\eta_p^2 = .75$. This difference did not reach significance for the HF-ASD group, $F(1,14) = 0.16$, $p = .69$. Note, emotion-identification and group-membership did not yield a significant interaction with target-emotion, $F(2,32) = 0.64$, $p = .53$.

As a final analysis, we tested whether individual scores on the verbal matriculation and on the SCQ correlate with the identification of spoken emotion (we note, that scores on these scales were not available for all participants). For that end, we derived an identification score from the data, as the difference between ratings of target-emotion-present and target-emotion-absent sentences (see the top two lines of Table 2). No significant correlation was found between the verbal (matriculation) score and identification of lexical content ($p > .48$) and prosodic content ($p > .15$) for either group. Similarly, no significant correlation was found between SCQ and identification of lexical content ($p > 0.90$) and prosodic content ($p > .1$) for either group.

In sum, it appears that both groups were able to successfully perform the tasks and identify emotions in both the lexical and prosodic channels. However, the results showed that only for the TD group, emotion-identification was higher in the prosodic channel than for the lexical one.

Selective Attention: Is There a Difference in Selective Attention to the Prosodic or the Lexical Channel, Between HF-ASD and TD Groups?

The description of the results of this section is portrayed in the middle rows of Table 2. Here, we compared the ability to selectively attend to one of the auditory channels, while ignoring the other between the HF-ASD and TD groups. Specifically, we compared the difference between average ratings of sentences that present the target-emotion *only* in the to-be-ignored channel, with sentences that do not present the target-emotion in either channel (Eq. 2 in Online Appendix). 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 lexical content, then anger lexical ratings of a lexically non-angry sentence "I really love nature" spoken with an angry prosody should be minimal, as no anger (target-emotion) is presented in the lexical content (target-channel). Similarly, anger prosodic ratings of a non-angry sentence "I won the lottery" spoken with a sad prosody should be equally minimal. In both cases, lexical anger is not present, thus lexical ratings for anger should not differ between the two. Yet, if listeners cannot ignore the prosodic anger, differences would appear.

We conducted a $2 \times 2 \times 3 \times 2$ mixed model ANOVA with selective attention (target-emotion-present or -absent in the to-be-ignored channel), target-channel (prosodic- vs. lexical-rating) and target-emotion (anger, happy or sad) as within-participants variables, and group-membership (HF-ASD or TD) as a between-participants variable.

Results show a significant main effect for selective attention, indicating failures of selective attention for both groups across all emotions, $F(1,33) = 45.2$, $p < .001$, $\eta_p^2 = .58$. No significant main effect for group-membership was found, $F(1,33) = 1.98$, $p = .17$, nor a significant interaction between the two factors (group-membership and selective attention), $F(1,33) = 0.26$, $p = .62$. A significant interaction of selective attention with target-channel factors was found, $F(1,33) = 19.1$, $p < .001$, $\eta_p^2 = .37$. This indicates larger failures when listeners were asked to inhibit the prosody rather than the lexical content (*Mean difference* = 0.15 vs. 0.54). However, no triple interaction of selective attention, target-channel and group-membership was found, $F(1,33) = 0.13$, $p = .72$. Moreover, we did not find a significant triple-interaction of target-emotion, group and selective attention, $F(2,32) = 0.38$, $p = .69$.

In sum, both groups performed with a similar degree of failure of selective attention, with a comparable bias to the prosodic channel. In other words, no group differences were found.

Integration of Channels and Channel Dominance: Is There a Difference in the Weights Assigned to the Prosodic and Lexical Channel, Between HF-ASD and TD Groups?

The description of the results of this section is portrayed in the bottom rows of Table 2. Figure 2 presents a graphic description of ratings in the General-rating Task, averaged across the three emotion-rating blocks, separately for HF-ASD and TD, for congruent trials (the target-emotion appears in both channels), prosody trials (the target-emotion appears only in the prosody), lexical trials (the target-emotion appears only in the lexical content) and target-emotion-absent trials (the target-emotion does not appear in either the lexical content or the prosody). The most notable feature

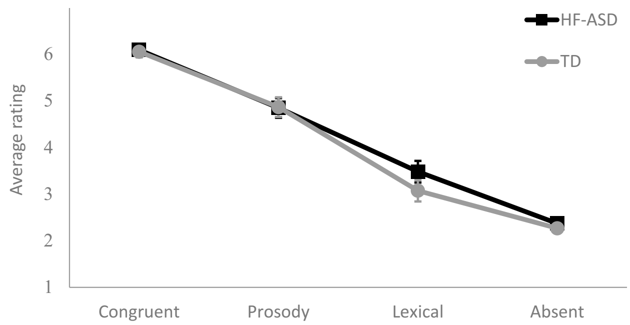


Fig. 2 A graphic description of ratings in the General-rating Task, averaged across the three emotion-rating blocks, separately for HF-ASD (black line) and TD (gray line), for congruent, prosody, lexical and target-emotion-absent trials. The error bars are standard errors of their respective means

of Fig. 2 is the apparent lack of any difference between the two groups. Namely, the results suggest that performance for both HF-ASD and TD follows the same linear trend: (1) Congruent trials received the highest emotional ratings for both HF-ASD and TD (5.59/6 and 5.55/6, respectively), with (2) prosodic trials following (4.35/6 and 4.36/6, respectively), then (3) lexical trials (2.98/6 and 2.58/6, respectively), and finally (4) lowest ratings for target-emotion-absent trials (1.87/6 and 1.77/6, respectively). These findings replicate the linear trend obtained in the original T-RES study (Ben-David et al. 2016b) with 80 TD students: congruent- > prosody- > lexical- > target-emotion-absent- trials.

In the mixed-model ANOVA (1 × 3 × 2), we tested the linear trend (congruent- > prosody- > lexical- > target-emotion-absent- trials) with target-emotion (anger, happy or sad) as within-participants variables, and group-membership (HF-ASD and TD) as a between-participants variable. The linear trend was found to be significant, $F(1,33) = 513.6$, $p < .001$, $\eta_p^2 = .94$, with no main effect for group-membership, $F(1,33) = 2.28$, $p = .14$. The two variables (linear trend and group-membership) did not interact, $F(1,33) = 0.32$, $p = .57$. In other words, both HF-ASD and TD performance indicated the same linear trend. Follow-up analyses verified that (1) Congruent sentences were rated higher than prosodic ones, $F(1,33) = 55.6$, $p < .001$, $\eta_p^2 = .63$, with no interaction with group, $F(1,33) = .03$, $p = .86$; (2) Prosodic sentences were rated higher than lexical ones, $F(1,33) = 29.7$, $p < .001$, $\eta_p^2 = .47$, with no interaction with group, $F(1,33) = 0.55$, $p = .46$, and (3) Lexical sentences were rated higher than sentences that target-emotion-absent ones, $F(1,33) = 45.3$, $p < .001$, $\eta_p^2 = .58$, with no interaction with group, $F(1,33) = 1.15$, $p = .29$.

In addition, the target-emotion did not interact with the linear trend, $F(1,33) = 0.28$, $p = .6$, nor with linear trend and group-membership, $F(1,33) = 0.08$, $p = .78$. In other words, neither the extent of the trend (congruent- > prosody- > lexical- > target-emotion-absent- trials) nor its interaction with group membership differed significantly across the three emotions (happy, anger and sad). Moreover, there was no triple interaction of target-emotion, group-membership and the factors reported above: (1) The comparison of congruent and prosody trials, $F(2,66) = 0.36$, $p = .7$; (2) The comparison of prosody and lexical trials, $F(2,66) = 0.48$, $p = .6$; (3) The comparison of lexical and target-emotion-absent trials, $F(2,66) = 1.5$, $p = .22$.

To further validate the results, separate analyses were conducted for baseline sentences, comparing lexically neutral sentences that carry the target-emotion in the prosody, with neutral prosody sentences that carry the target-emotion in the lexical content. Here, even when emotion integration (or possibly inhibition) was minimized, we found a significant prosodic dominance, $F(1,33) = 67.7$, $p < .001$, $\eta_p^2 = .67$, that did not significantly interact with group, $F(1,33) = 0.89$, $p = .35$.

To recap, the HF-ASD group appears to assign relative weights to the prosodic and lexical channels in the same fashion as the TD group.

Effects of Symptom Severity on the Perception of Emotions in Speech for the HF-ASD Group

Even though the HF-ASD group is relatively homogeneous, there are differences in the severity of symptoms, as gauged by the AQ scores. In a follow-up, we conducted a correlation analysis for the HF-ASD group. AQ score was not found to correlate significantly with correct identification of emotions (the advantage in average rating of target-emotion-present over -absent trials, Eq. 1 in Online Appendix), $r_p(21) = .09$, $p = .7$. AQ was also not correlated with selective attention (target-emotion-present over -absent in the to-be-ignored channel, Eq. 2 in Online Appendix), $r_p(21) = .06$, $p = .79$. Finally, the AQ score was not correlated with prosodic dominance (target-emotion-prosody over -semantics trials, Eq. 3 in Online Appendix), $r_p(21) = .12$, $p = .63$. In sum, the severity of symptoms as documented by the AQ scale did not affect our main tested variables.

Discussion

Impairments in social behavior and social relationships form a core symptom of ASD (Loveland et al. 1997). The pervasive effect of these deficits is extensive. Even individuals with HF-ASD with high cognitive and linguistic abilities often present difficulties in forming friendships, in appropriate behavior at work settings and in managing daily social interactions with peers (Spain and Blainey 2015; Volkmar et al. 1987). One of the most prominent clinical features of these social deficits is the difficulty in the identification of various emotional signals available in the social environment (Baron-Cohen et al. 1997; Hobson 1993), such as spoken emotions (Hadjikhani and de Gelder 2003). These difficulties can stem from impairments in processing the prosodic (tone of speech) channel, the lexical (semantic content) channel, or the integration of the two. To the best of our knowledge, these topics were not yet tested in individuals with HF-ASD. Moreover, it appears that attention in the auditory modality is a somewhat neglected topic in the study of HF-ASD. The current study aimed to fill this gap, by comparing a group of HF-ASD undergraduates with TD peers in their performance on a novel emotional speech processing test, T-RES.

The results of the current study did not indicate any difference between the two groups in the processing of emotions in speech in any of the analyses conducted. In other words, students with HF-ASD performed similarly to their TD peers. Specifically, (1) they were similarly correct at identifying emotions expressed by the prosody and by the lexical content; (2) they showed failures of selective attention tasks to the same extent as their TD peers; and (3) when integration of lexical and prosodic information was required, they demonstrated a tendency for making emotion decisions mainly on the basis of the prosodic channel (prosodic dominance) similarly to their TD peers. It is important to note that the same students with HF-ASD, whose performance on the speech task (T-RES) indicated preserved ability to process spoken emotions, scored lower than the threshold on several standardized ASD measures. These findings call to revisit some of the assumptions related to the processing of emotions in HF-ASD, as we discuss next.

Identification of Emotions in the Prosody and Lexical Content

Our data indicate that HF-ASD students can identify the emotion presented in the prosodic and the lexical channels as well as their TD peers. This result replicates similar findings on identification of the prosodic channel (Baker et al. 2010; Kujala et al. 2005; O'Connor 2007). Indeed, Golan et al. (2007) have already noted that verbal IQ in adults with HF-ASD positively correlates with identification of emotions in speech.

Our data also form an important addition to the current literature, as (to the best of our knowledge) no study to date has focused on perception of emotions in the lexical channel of spoken language (auditory modality). Notably, HF-ASD students were found to understand emotions expressed by the lexical content to the same level as TD students. This finding is even more noteworthy as the great majority of T-RES sentences (20 out of 24) convey the target lexical emotions implicitly (e.g., "You've won first place") rather than explicitly (e.g., "I am so happy"). This ability to correctly identify implicit lexical emotions may stem from the relatively preserved vocabulary and verbal abilities that characterize this special population of HF-ASD (e.g., Lindner and Rosen 2006).

It is notable that emotion-identification was higher in the prosodic channel than for the lexical one only for the TD group. That is, TD group members provided numerically higher ratings on the prosodic than on lexical rating task. We maintain that this finding is only secondary in importance, as the main finding is that both HF-ASD and TD groups in our study successfully identified prosodic and semantic emotions. That is, both groups provided target-emotion-present sentences average ratings above 5.0/6 in both channels, indicating very high agreement that the target-emotion was present in the target-channel. Whereas target-emotion-absent sentences received average ratings below 2.0/6 in both channels, indicating very high agreement that the target-emotion was absent from the target-channel. Namely, both groups provided ratings that indicate very high ability to differentiate between target-emotion-present and -absent sentences in both prosodic and lexical channels, indicating high similarity in the identification of spoken emotions.

A possible explanation for our findings was suggested by Loveland and colleagues (1997). Their study investigated verbal and non-verbal perceptions of emotion in children, adolescents and young adults with low- and high-functioning ASD. The participants identified emotions shown in video clips of individuals expressing emotion verbally, nonverbally, or both. The results indicated group differences between higher- and lower- functioning individuals, suggesting that the ability to perceive emotions depends primarily on cognitive level rather than on the presence of ASD.

Another possible reason may relate to the type of emotions examined in the current study. The three examined emotions, happiness, sadness and anger, are considered basic emotions (Ekman 1992). Identification of these universal emotions is considered primary and demand less cognitive processing resources (Barrett et al. 2011). However, identifying complex emotions, such as boredom and envy, may require more cognitive resources, as they are belief-based, context- and culture-dependent (Harris 1989). Further studies should examine identification abilities in HF-ASD population of such abstract emotions, which may call for more complex theory-of-mind abilities.

Inhibition of Emotional Content (in the Prosodic or Lexical Channel)

Inhibitory control is a mandatory aspect of daily functions, especially in academic settings. For example, a typical classroom behavior involves separating the target speech of the lecturer from irrelevant background noises, such as classmates' speech and environmental noises (e.g., air conditioner; for a related discussion, see: Mama et al. 2018). In our study, no group-differences in the extent of inhibitory control of prosodic- as well as spoken lexical-content were found.

A recent meta-analysis by Geurts and colleagues (2014) suggests that individuals with ASD may exhibit difficulties in inhibition. Yet, an increase in cognitive abilities (e.g., IQ) was found to minimize group differences. Even when differences in inhibition were noted between HF-ASD and TD groups, it appears that the HF-ASD group performed within the normative range (e.g., Schwean and Montgomery 2015). Geurts et al. (2014) further suggested that difficulties in inhibition in ASD do not encompass all inhibitory activities. Namely, distractor-resistance as tested by the flanker task (Eriksen and Eriksen 1974) is not necessarily affected by ASD. Indeed, the inhibitory abilities tested by our task (T-RES) are highly similar to this taxonomy. A study by Geurts and colleagues (Geurts et al. 2009) is noteworthy in this respect, as they further did not find a decrease in efficiency of inhibition in individuals with HF-ASD in a task involving inhibition of emotions in visual facial expressions (see also, de Vries and Geurts 2012).

Our findings join other studies in the literature that similarly suggest that inhibitory function, specifically distractor-resistance may be spared in HF-ASD (e.g., Adams and Jarrold 2009). The current study also extends the literature to the auditory modality and auditory emotional stimuli. As social adaptation requires specific cognitive and emotional competences, these preserved inhibitory abilities may be used in future programs to support students with HF-ASD to successfully engage in social relationships. Future examinations should also explore the possible effect of environmental noises on the identification of lexical and prosodic emotions in speech (see, Nitsan et al. 2019) and their retention (see, Mama et al. 2018) in people with HF-ASD.

Integration of Channels: Prosodic Dominance

Previous research has indicated that TD listeners tend to judge the emotional content of spoken sentences based on the *prosodic* channel. Specifically, when the emotions presented by the prosody and by the lexical content are incongruent, TD listeners allocate more weight to the prosodic channel than to the lexical one—a *prosodic dominance* (Mehrabian and Wiener 1967; Jacob et al. 2014; Morton and Trehub 2001). This is the first study to demonstrate that HF-ASD students show the exact same pattern as TD in integrating auditory channels, namely prosodic dominance. Our results somewhat follow data by Loveland et al. (1997), reporting that individuals with HF-ASD relied more on nonverbal (i.e. prosody and facial) than on verbal information to determine a speaker's emotion (except where the emotion was explicitly named). In contrast, there is some evidence that adults with ASD may have difficulties using non-emotional prosodic cues to disambiguate lexical content. For example, Diehl and colleagues (Diehl et al. 2008) have shown that adolescents with HF-ASD experienced difficulties using non-emotional prosody to resolve syntactically ambiguous sentences. Similarly, Paul et al. (2005) found that adolescents with ASD were less accurate than TD in using non-emotional prosody (stress) to decide between two meanings of the same word (e.g., RECALL vs. reCALL).

We believe that our data showcase the unique advantage that students with HF-ASD have in correctly identifying spoken emotional cues. Moreover, as prosodic dominance is an implicitly learned "rule", based on experience in social interactions (Ben-David et al. 2016b), our data suggest that individuals with HF-ASD can learn and employ the socially accepted rules on how the prosodic and lexical channels should be integrated. This ability may rely on the preserved intellectual aptitudes of this unique population.

Limitations and Future Studies

There are limitations related to our sample, as we focused on undergrads with HF-ASD who attended the unique integration program. First, our group is a unique group of motivated individuals who were selected based on their academic potential. Second, all HF-ASD students included in our study met the inclusion diagnosis. However, details about their clinical diagnoses were not available (due to privacy concerns). This did not allow us to fully control potential confounding factors (e.g., comorbidity). Yet, as in-group variance was very limited, and no group-related differences were found, we deem these influences unlikely. Moreover, note that several measures (verbal matriculation and SCQ) were obtained and tested against T-RES performance, with no significant effects.

There are also limitations related to the T-RES itself. (1) T-RES stimuli are recorded by a single trained professional female actress, rather than different speakers. This may potentially decrease the generalizability of our data, yet, we maintain that this choice minimizes sources for variation. (2) As noted in a series of studies by Kitayama and Ishii (Ishii et al. 2003; Kitayama and Ishii 2002), the perception of emotions in speech may be culturally bound. The current study tested only native-Hebrew speakers with the Hebrew version of the T-RES. Future studies may wish to examine the validity of our conclusions when testing material recorded by multiple speakers, testing individuals from various cultures/languages (see Icht and Ben-David 2014). (3) The T-RES includes basic and concrete emotions. It is possible that group differences will be uncovered when abstract emotions would be tested in this population. Future studies may wish to examine these emotions, both in the spoken modality and in written sentences (see Ben-David et al. 2016a). (4) It is possible that the T-RES as a lab measure is not sensitive enough to detect group differences that might be uncovered by tracking performance in daily activities.

Even though the T-RES involves processing of incongruent emotions expressed by the prosodic and lexical channels, it does not test the subtle abilities to understand humor, irony or sarcasm (i.e. a discrepancy between the expected emotion and the one that is used). Indeed, there is some evidence in the literature to suggest difficulties in these abilities for individuals with HF-ASD (Happé 1995). However, as our study finds individuals with HF-ASD to be equally biased to the prosodic content as TD, this may suggest that the picture is more complex. Further studies may directly address this issue and also address multi-modal processing of emotions, where both auditory and visual information are available (e.g., a video of the actress). Finally, one may note that we did not include self-reports on processing of emotions in speech. A recent literature review (Leshem et al. 2019) suggests that responses on self-reports on alexithymia (deficits in emotion processing and verbal expressions) may be related to emotional speech processing. To date, we could not retrieve any experimental data on this link in the target population. This calls for future explorations.

Summary and Clinical Implications

Taken together, the results of the current study suggest that students with HF-ASD can use affective information in speech, in regard to simple emotions, in the same way as their TD counterparts. First, they can successfully identify the three tested basic emotions (anger, sadness and happiness) presented in the prosodic and lexical channels, separately. Second, HF-ASD students can selectively attend to the emotional content in the target-channel (prosody or lexical) to the same extent as TD matched controls. Finally, when asked to judge the emotional content of a spoken sentence, students with HF-ASD integrate the prosodic and lexical channels in the same manner as TD matched controls. Namely, they show a prosodic dominance, assigning a larger role to the prosodic over the lexical channel.

The processing of spoken emotions is a basic, everyday ability, essential for social functioning. The fact that this ability is intact for the special group of HF-ASD students may suggest their potential to effectively integrate into campus life, and to succeed in academic tasks as well as in social interactions. We suggest that inclusion programs for ASD students should consider relying on these well-preserved abilities to promote other areas of functional difficulties. We wish to caution this, by acknowledging that we tested very basic emotions. However, the lack of any group difference in processing sentences that present conflicting emotions (in the prosody and the lexical content) may provide hope for integration efforts.

Author Contributions All authors contributed to the research equally. BBD and MI take the leading author responsibility.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (include name of committee + reference number) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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