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RESEARCH ARTICLE

Keep it simple: Identification of basic versus complex emotions in spoken language in individuals with autism spectrum disorder without intellectual disability: A meta-analysis study

Michal Icht[1] | Gil Zukerman[1] | Esther Ben-Itzchak[1,2] | Boaz M. Ben-David[3,4,5]

[1]Department of Communication Disorders, Ariel University, Ariel, Israel

[2]The Bruckner Center for Research in Autism, Department of Communication Disorders, Ariel University, Ariel, Israel

[3]Baruch Ivcher School of Psychology, Interdisciplinary Center (IDC) Herzliya, Herzliya, Israel

[4]Department of Speech-Language Pathology, and Rehabilitation Sciences Institute (RSI), University of Toronto, Toronto, Ontario, Canada

[5]Toronto Rehabilitation Institute, University Health Networks (UHN), Toronto, Ontario, Canada

Correspondence
Boaz M. Ben-David, Communication, Aging and Neuropsychology Lab (CANlab), School of Psychology, Interdisciplinary Center, Herzliya, P.O. Box 167, Herzliya, 4610101, Israel.
Email: boaz.ben.david@idc.ac.il

Abstract

Daily functioning involves identifying emotions in spoken language, a fundamental aspect of social interactions. To date, there is inconsistent evidence in the literature on whether individuals with autism spectrum disorder without intellectual disability (ASD-without-ID) experience difficulties in identification of spoken emotions. We conducted a meta-analysis (literature search following the PRISMA guidelines), with 26 data sets (taken from 23 peer-reviewed journal articles) comparing individuals with ASD-without-ID ($N = 614$) and typically-developed (TD) controls ($N = 640$), from nine countries and in seven languages (published until February 2020). In our analyses there was no sufficient evidence to suggest that individuals with HF-ASD differ from matched controls in the identification of simple prosodic emotions (e.g., sadness, happiness). However, individuals with ASD-without-ID were found to perform significantly worse than controls in identification of complex prosodic emotions (e.g., envy and boredom). The level of the semantic content of the stimuli presented (e.g., sentences vs. strings of digits) was not found to have an impact on the results. In conclusion, the difference in findings between simple and complex emotions calls for a new-look on emotion processing in ASD-without-ID. Intervention programs may rely on the intact abilities of individuals with ASD-without-ID to process simple emotions and target improved performance with complex emotions.

Lay summary: Individuals with autism spectrum disorder without intellectual disability (ASD-without-ID) do not differ from matched controls in the identification of simple prosodic emotions (e.g., sadness, happiness). However, they were found to perform significantly worse than controls in the identification of complex prosodic emotions (e.g., envy, boredom). This was found in a meta-analysis of 26 data sets with 1254 participants from nine countries and in seven languages. Intervention programs may rely on the intact abilities of individuals with ASD-without-ID to process simple emotions.

KEYWORDS
ASD-without-ID, emotions, prosody, social cognition, speech perception

INTRODUCTION

Spoken communication, and specifically the identification of emotions in spoken language, is a core aspect of social interactions (Ben-David et al., 2016; Kotz & Paulmann, 2007; Loveland et al., 1997. For a review, see: Juslin & Laukka, 2003). Perceiving spoken emotions in social interactions involves combining information from various sources. In the absence of visual cues (e.g., during a phone conversation), or when visual information is degraded, the main sources of information are the two auditory channels: the semantic channel (lexical content—the meaning of the words) and the prosodic channel (intonation of voice). Difficulties in the identification of the emotions expressed by these auditory channels may lead to miscommunication with possible negative implications on quality of life and social well-being (Hudepohl et al., 2015).

Understanding (recognition and interpretation) of emotional cues has generally been found to be impaired in individuals with Autism Spectrum Disorder (ASD; Bellini, 2004), possibly leading to social difficulties. ASD is a neurodevelopmental disorder characterized by deficits in social communication and restricted, repetitive behaviors (DSM-V, American Psychiatric Association, 2013). ASD is considered a heterogeneous condition that includes a wide range of symptom severity (Wingate et al., 2014), changes in cognitive ability (Grzadzinski et al., 2013), and changes in verbal ability (Anderson et al., 2007; Boucher, 2012).

In recent decades, the special subgroup of individuals with ASD without Intellectual disability (ASD-without-ID, also referred to as people with High Function ASD) has attracted much research. ASD-without-ID relates to cognitively able people with ASD (IQ ≥70; within 2 *SD* below the mean) and language abilities (Baron-Cohen et al., 1999; Sanders, 2009). Although these individuals do not have comorbid ID (at times referred to as ASD of normal intelligence), they exhibit reduced social cognition in comparison to their other cognitive abilities (Baron-Cohen et al., 1997), such as difficulties in perceiving basic facially expressed emotions (Baron-Cohen et al., 2000) as well as in adaptive behavior (Alvares et al., 2020).

On the other end, it has been suggested that relatively improved cognitive performance in this group may lead to relatively preserved emotional processing. For example, a review on children with ASD-without-ID by Kasari and colleagues (2001) indicates that verbal IQ is related to the understanding of emotions. This link between cognition and social functioning may be reciprocal for individuals with ASD. Namely, the presence of ID may limit social interactions, minimizing the opportunity to learn and exercise the processing of emotional cues. Indeed, children with ASD-without-ID were found to use their linguistic abilities to engage in higher levels of social interactions than their peers with ASD-with-ID (e.g., Hermelin and O'Connor 1985).

This group of individuals with ASD-without-ID is the focus of a concentrated effort for integration and participation in the mainstream educational system, from school to university, as well as in workplace and employment settings (Fried et al., 2013). Adequate social skills highly depend on spoken communication abilities, and on the ability to correctly identify social and emotional cues. Specifically, difficulties in understanding subtle emotional spoken messages, such as humor and sarcasm, may set individuals with ASD-without-ID apart from their peers (Adreon & Durocher, 2007). As aforementioned this link can be bi-directional, as increased social activity can enhance the processing of emotional cues (see, White et al., 2013). Therefore, assessing the perception of spoken emotions can assist in better understanding everyday functioning of individuals with ASD-without-ID and improving them (Lindner & Rosen, 2006).

Hitherto, the ASD-without-ID literature has mainly focused on the visual modality, gauging differences in the identification of emotions presented by facial expressions (e.g., Jones et al., 2011). Less is known on the auditory modality, an essential source for the identification of emotions in spoken language. The goal of the current study is to fill this gap by conducting a meta-analysis of the pertinent literature, and identifying the main trends.

ASD-without-id: identification of spoken emotions

The literature on the identification of spoken emotions in individuals with ASD-without-ID is inconsistent (see Ploog et al., 2014). Several studies indicate difficulties in identifying emotions via prosody. For example, Golan et al. (2006) found individuals with ASD-without-IDto made more mistakes than did their typically developed (TD) peers in the identification of complex emotions (e.g., resentful, grave and insincere) expressed via the prosody of spoken short sentences (see also Kleinman et al., 2001). Conversely, other studies failed to find differences in emotion identification of spoken stimuli between ASD-without-IDand TD populations. For example, O'Connor (2007) did not find a group difference in the identification of simple emotions expressed by the prosody of semantically neutral sentences. The author concluded that identification of emotions is related to cognitive abilities rather than merely the presence of ASD. Ben-David and colleagues (2020) also reported similar performance for ASD-without-ID and TD university students in prosodic identification of spoken sentences, in which the emotional lexical and prosodic content appeared in different combinations. Note, both latter studies tested the identification of simple emotions (happiness, anger, and sadness) rather than complex ones.

The pertinent literature suggests two main factors that may impact the ability of individuals with ASD-without-ID to identify spoken emotions:

Emotional complexity

The literature distinguishes simple (e.g., happiness and sadness) from complex (e.g., pride and embarrassment) emotions along several dimensions, including personal responsibility, normative standards, and the role of an audience (Capps et al., 1992). Understanding complex emotions requires relatively more cognitive resources than understanding simple emotions, as they are belief-based rather than situation-based (Harris, 1989), and call for advanced understanding of social and interpersonal situations. For example, discriminating between "joyfulness" and "pride" is based on the locus of the event (internal vs. external), the ability to control it (controllable vs. uncontrollable) and the presence of an audience (Seidner et al., 1988); while discriminating between "anger" and "happiness" could simply be based on the valence of the emotion, negative versus positive. Complex emotions are more context- and culture-dependent, whereas basic emotions are considered to be universal (e.g., see Ekman's classic categorization, Ekman, 1972). Taken together, it appears that the correct identification of complex emotions demands a more comprehensive understanding of social norms than does the identification of simple, basic emotions. We can hypothesize that individuals with ASD-without-ID can recruit their cognitive abilities to decipher simple spoken emotions, as suggested by the correlation between cognitive and affective abilities in this population (Capps et al., 1992; Yirmiya et al., 1992). However, these cognitive abilities may not be sufficient to distinguish between complex emotions (e.g., Golan et al., 2006).

Semantic content

Reviewing the literature, several different stimuli have been used to test the ability of individuals with ASD-without-ID to correctly identify emotional prosody. Some paradigms used *low-level semantics*, such as a string of numbers (Philip et al., 2010), a person's name (Doi et al., 2013), or nonverbal stimuli (e.g., vocalizations, Heaton et al., 2012). Others used *high-level semantics*, including sentences that carry emotional content (e.g., semantically angry sentences; Stewart et al., 2013). In the former case, the task calls the listener to only identify the prosodic cues, whereas in the latter, inhibition (or integration) of the semantics is also required (for reviews, see Ben-David et al., 2016, 2019; Oron et al., 2020). We can hypothesize that individuals with ASD-without-ID will show more difficulties as compared to TD in identification of emotional prosodies when inhibition of semantics is involved (see, Jones et al., 2011).

The current study

The goal of the current study was to perform a meta-analysis of the literature on the identification of basic and complex prosodic emotions in spoken language for adults with ASD-without-ID, controlling for the semantic content of the stimuli. The current analysis does not aim to provide a general scope on ASD, given the high heterogeneity. The literature presented above could lead to two contrasting hypotheses: (a) as individuals with ASD-without-ID have difficulties in identifying emotions in the visual domain, they will also have difficulties in identifying prosodic emotions. Conversely, (b) individuals with ASD-without-ID may be able to use their cognitive abilities (Adreon & Durocher, 2007) to compensate for losses, and perform similarly to TD individuals. We also explored the effects of Emotional complexity (complex or simple emotions) and Semantic content (high or low level), which may moderate the impact of ASD-without-ID on emotional processing.

Study selection followed the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analysis; Moher, Liberati, Tetzlaff, Altman,, & Prisma Group, 2009), and study quality was assessed using the GRADE approach (Higgins & Green, 2011). We conducted a meta-analysis of 26 data sets (taken from 23 peer-reviewed journal articles), published until February 2020.

METHOD

Literature search

A search was conducted (during the period of July 2018–February 2020) using the following online resources: Google Scholar, PsycINFO, PubMed, and JSTOR. We used a diverse list of search terms and keywords: autism, autism spectrum disorder (ASD), ASD, high functioning autism spectrum disorder, high-functioning ASD (HF-ASD), HF-ASD, Asperger's Syndrome (AS), AS, adults, emotion perception/recognition/identification, voice, prosody, and intonation.[i] The references in the retrieved articles were also consulted in order to identify additional suitable studies. In one case, data were obtained by personal communication with the author (Jones et al., 2011). We selected studies, published until February 2020, with the following criteria: (a) Data are included for two groups—an experimental group of cognitively able individuals with ASD (IQ > 70; whether diagnosed with HF-ASD or AS), as well as an age-matched TD control group; (b) appropriate participants' selection is ensured by identification of ASD using accepted diagnostic criteria (as detailed in Table 1); (c) participants are adolescents and/or adults (mean age for the clinical group ≥12 and < 60 years); and (d) at least one task of spoken emotion identification, in which emotions are presented by the prosody, is included.

Figure 1 presents the stages of literature search as conducted following the PRISMA guidelines (a flow chart). After excluding papers based on title and abstract (see Figure 1), 47 relevant studies were assessed for eligibility by reviewing the full text, and 23 met the above depicted criteria. The main reasons for excluding studies from the meta-analysis were: lack of a control group, a focus on children (mean age younger than 12 years old), and studies that did not include semantics or prosody (usually only facial expressions). Overall, 26 data sets from 23 studies were analyzed. These studies include 1254 participants, 614 individuals with ASD-without-ID (HF-ASD and/or AS) and 640 matched TD controls. The studies were conducted in nine countries, in seven different languages, used different measures for ASD

TABLE 1 Details on the data sets included in the meta-analysis, arranged by effect size (Hedges' g; lowest to highest)

Panel a: Identification of simple emotions (e.g., anger, happy, fear, sad, surprise, disgust).

			Study group			Control group			
Study		Country (language)	*N*	Age, years M (range)	Diagnosis (tests)	*N*	Age, years M (range)	Material spoken with different prosodies (example)	Hedges' g (CI lower, higher limit)
1	Grossman and Tager-Flusberg (2012)	US (English)	22	14 (9–20)	ASD (2,3)	22	14 (10–17)	Semantically neutral stimuli ("He wants to sell his car"), in a discrimination task (choosing one of the presented facial expressions that matches the prosodic emotion).	−0.22 (−0.79, 0.35)
2	Rosenblau et al. (2017)[a]	Germany (German)	20	32 (19–47)	HF-ASD, AS (2, 3, 7)	21	32 (20–46)	Neutral sentences	0.00 (−0.62, 0.62)
3	Baker et al. (2010)	USA (English)	19	13 (10–14)	HF-ASD, AS (2, 3, 8)	19	12 (10–14)	Nonsense stimuli (different pseudo-sentences simultaneously presented to both ears) in dichotic listening	0.06 (−0.58, 0.71)
4	Jones et al. (2011)	UK (English)	99	16	ASD (2, 3, 9)	57	15 (14–16)	Verbal stimuli (three-digit numbers), and non-verbal expressions (e.g., crying vocalizations for sadness)	0.11 (−0.22, 0.44)
5	Chevallier et al. (2011)	UK (English)	17	14 (11–17)	ASD (5)	17	14 (12–17)	Sentences with a neutral content and a marked prosodic contour (e.g., "Ben hears a big noise from his neighbors' house. He says: What is that noise?")	0.12 (−0.56, 0.81)
6	O'Connor (2007)	NZ (English)	18	27 (19–50)	AS (5, 7)	18	25 (19–47)	Semantically neutral sentence ("I want to go to the other movies.")	0.23 (−0.43, 090)
7	Ketelaars et al. (2016)	The Netherlands (Dutch)	31	41 (*SD* = 11)	HF-ASD (5)	28	40 (*SD* = 13)	Neutral sentences	0.24 (−0.27, 0.76)
8	Ben-David, Ben-Itzchak, et al. (2020)	Israel (Hebrew)	20	23 (19–27)	HF-ASD (4,9)	20	24 (22–29)	Emotional or neutral sentences, congruent, incongruent, and neutral prosody	0.34 (−0.28, 0.98)
9	Heikkinen et al. (2010)	FIN (Finnish)	12	15 (13–16)	AS (2, 3)	15	14 (13–16)	Sentences (neutral content, e,g., "Everything is fine again.")	0.40 (−0.37, 1.19)
10	Tobe et al. (2016)	USA (English)	19	39 (*SD* = 13)	HF-ASD (11)	73	36 (*SD* = 12)	Neutral sentences	0.41 (−0.10, 0.92)

(Continues)

TABLE 1 (Continued)

Panel a: Identification of simple emotions (e.g., anger, happy, fear, sad, surprise, disgust).

			Study group			Control group			
Study		Country (language)	*N*	Age, years M (range)	Diagnosis (tests)	*N*	Age, years M (range)	Material spoken with different prosodies (example)	Hedges' g (CI lower, higher limit)
11	Doi et al. (2013)	JAP (Japanese)	22	32 (18–65)	AS (4)	20	33 (18–65)	A person's name (/su-zu-ki-san/)	0.59 (−0.03, 1.22)
12	Charbonneau et al. (2013)	CAN (French)	32	21 (14–32)	ASD/ F-ASD (2, 3)	18	21 (15–27)	Emotional non-verbal vocal expressions	0.67 (0.08, 1.27)
13	Brennand et al. (2011)	UK (English)	15	15 (11–19)	AS (5)	15	13 (11–17)	Nonsense (pseudo-) sentences spoken with affective prosody	0.69 (−0.04, 1.46)
14	Globerson et al. (2015)	Israel (Hebrew)	20	29 (20–40)	HF-ASD (3, 4)	32	26 (23–39)	Utterances (nonsense monosyllabic and polysyllabic words, words and sentences)	0.79 (0.24, 1.36)
15	Kleinman et al. (2001)[a]	USA (English)	24	31 ($SD = 8$)	HF-ASD (1)	24	22 ($SD = 6$)	A fixed sentence with varying emotional intonations	1.09 (0.49, 1.72)
16	Stewart et al. (2013)	UK (English)	11	(17–39)	ASC (5)	14	(17–39)	Emotional or neutral sentences (e.g., "Stop that at once!", "He drank a cup of tea."), congruent, incongruent and neutral prosody—semantics pairs. Non-verbal stimuli (vocalizations of "mmm")	1.33 (0.48, 2.27)
17	Philip et al. (2010)	UK (English)	23	33	ASD/AS/HF-ASD (3, 4, 6)	23	32	Strings of numbers	1.46 (0.83, 2.15)
18	Heaton et al. (2012)	UK (English)	20	33 (20–67)	ASD (4)	20	33 (20–67)	Non-verbal stimuli (e.g., laughing vocalizations for happiness); verbal stimuli (three-digit numbers)	2.39 (1.61, 3.27)

Panel b: Identification of complex emotions (e.g., defiance, intimate, insincere).

			Study group			Control group			
Study		Country (language)	*N*	Age, years M (range)	Diagnosis (tests)	*N*	Age, years M (range)	Material spoken with different prosodies (example)	Hedges' g (CI lower, higher limit)
1	Rosenblau et al. (2017)[a]	Germany (German)	20	32 (19–47)	HF-ASD, AS (2, 3, 7)	21	32 (20–46)	Neutral sentences	0.27 (−0.35, 0.9)

(Continues)

TABLE 1 (Continued)

Panel b: Identification of complex emotions (e.g., defiance, intimate, insincere).

			Study group			**Control group**			
	Study	**Country (language)**	***N***	**Age, years M (range)**	**Diagnosis (tests)**	***N***	**Age, years M (range)**	**Material spoken with different prosodies (example)**	**Hedges' g (CI lower, higher limit)**
2	Kujala et al. (2005)	FIN (Finnish)	8	33 (22–43)	AS (5, 7)	8	32 (23–42)	Naturally articulated words	0.37 (−0.63, 1.42)
3	Rutherford et al. (Rutherford et al., 2002)	CAN (English)	19	19 (15–59)	HF-ASD/AS (2, 3, 4)	78	36 (18–53)	Sentences with semantic content (e.g., "Please! We must go.")	0.69 (0.20, 1.20)
4	Golan & Baron-Cohen (2006, Exp. 1)	UK (English)	41	31 (17–52)	AS/HFA (4)	24	25 (18–51)	Short sentences	0.80 (0.28, 1.33)
5	Golan & Baron-Cohen (2006, Exp. 2)	UK (English)	26	25 (17–50)	AS/HFA (4)	13	25 (17–51)	Short sentences	1.02 (0.32, 1.75)
6	Golan et al. (2007)	UK (English)	50	28 (17–50)	AS/HF-ASD (5)	22	28 (17–50)	Sentences with semantic content (e.g., "Yeah, well, I know nothing about that.")	1.36 (0.82, 1.93)
7	Golan et al. (2006)	UK (English)	21	30 (18–50)	AS (5)	21	27 (18–51)	Short sentences	1.47 (0.77, 2.24)
8	Kleinman et al. (2001)[b]	USA (English)	24	31 (*SD* =8)	HF-ASD (1)	24	22 (*SD* = 6)	A fixed sentence with varying emotional intonations	1.49 (0.87, 2.17)

Abbreviations: AS, Asperger's syndrome; ASC, autism spectrum conditions; ASD, autistic spectrum disorder; HF-ASD, high functioning autistic spectrum disorder.
Note: Shaded rows indicate that lower CIs do not cross zero. Diagnostic instruments: (1) Childhood Autism Rating Scale (CARS; Schopler et al., 1988). (2) Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994). (3) Autistic Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000). (4) Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001). (5) Tools unspecified. (6) Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004), Systemizing Quotient (SQ; Baron-Cohen et al., 2003). (7) A detailed interview (Gillberg & Gillberg, 1989). (8) Asperger Syndrome Diagnostic Scale (ASDS; Myles et al., 2001). (9) The Social Communication Questionnaire (SCQ; Rutter et al., 2003). (10) Adaptive Behavior Assessment System (ABAS-II; Harrison & Oakland, 2003). (11) Structured Clinical Interview for DSM-IV (SCID) (First et al., 1994).
[a]The data set for complex emotions is included.
[b]The data set for simple emotions is included.

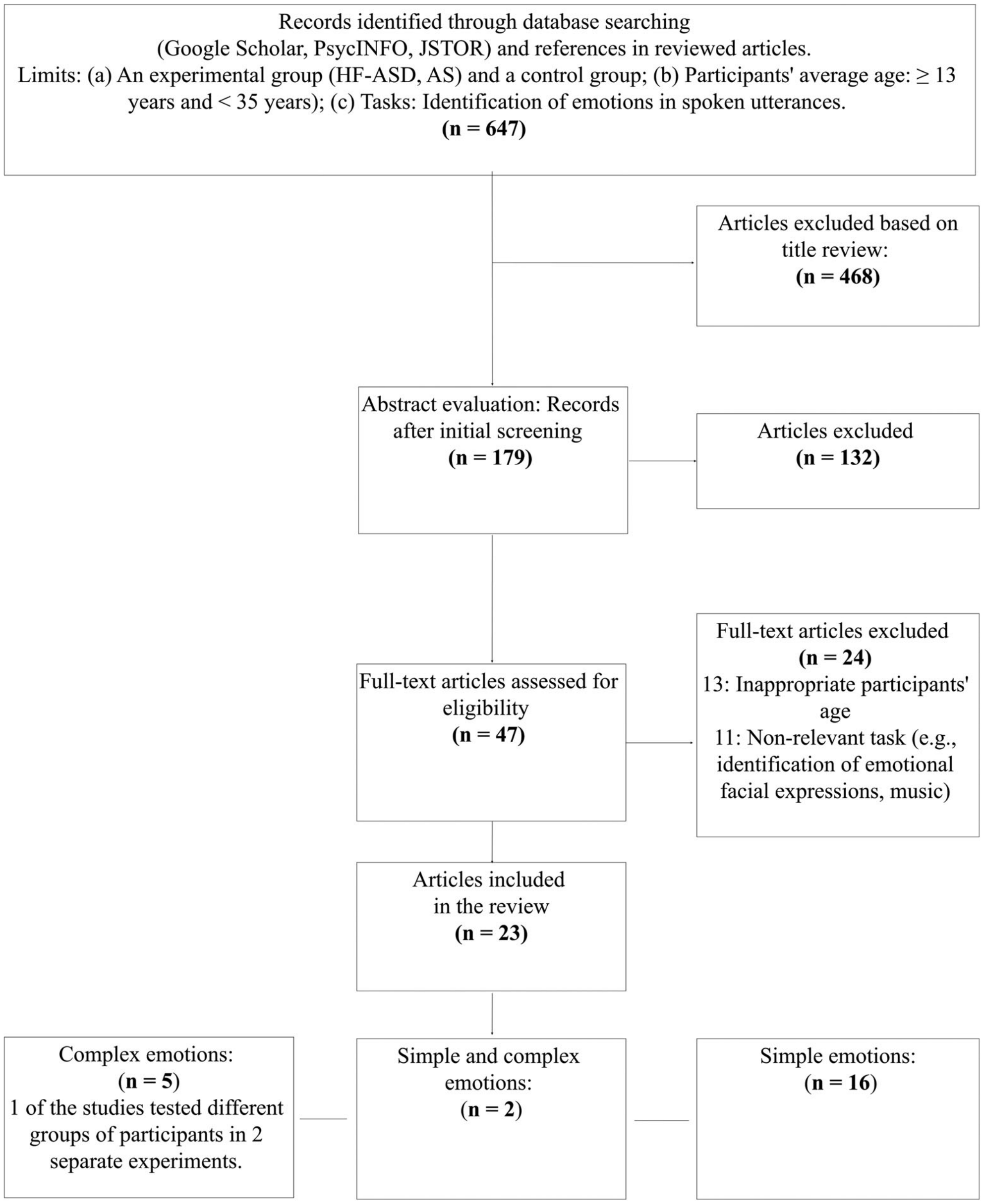

FIGURE 1 Flow chat—stages of literature search as conducted following the PRISMA guidelines

diagnosis, and employed varied tools to gauge spoken emotion identification, illustrating the relatively high degree of variability between studies. Table 1a,b present the lists of the selected studies and data sets, focusing on simple and complex emotions, respectively, along with the studies' respective characteristics (the measures used to confirm ASD diagnosis, participants' age, the tasks employed, the material used, and main results).

Quality assessment

Two independent reviewers (the first author and the corresponding author) scored the included studies according to the GRADE approach (as detailed in the Cochrane Handbook; Higgins & Green, 2011), a quality tool that defines four levels of evidence (High, Moderate, Low, and Very Low). The highest quality rating is for randomized trial evidence (randomized control trials, RCT). Moderate quality is for downgraded randomized trials or upgraded observational studies. Low quality rating is for double downgraded randomized trials or observational studies. Very Low quality is for triple-downgraded randomized trials, downgraded observational studies, or case series/case reports. A study can be downgraded by one or more levels for every limitation factor an observer finds (e.g., limitations in the experimental design, imprecise results and indirectness of evidence). The chosen studies were summarized in data-extraction form. Due to differences in study designs and measurements, data were summarized separately for each study. In case of a disagreement between the reviewers about the quality assessment ($n = 3$ studies), the two consulted each other, until an agreement was achieved.

TABLE 2 Bias scores and GRADE scales for each paper included in the meta-analysis

Study	Bias score				Study quality, GRADE scale (limitations)
	Q1: Sample size	Q2: Exclusions	Q3: Outcomes	Q4: No conflict	
Grossman and Tager-Flusberg (2012)	No	Yes	Yes	Yes	Low (5)
Rosenblau et al. (2017)	No	Yes	Yes	Yes	Moderate
Baker et al. (2010)	No	Yes	Yes	Yes	Low (5)
Jones et al. (2011)	No	N/A	No (1)	Yes	Moderate
Chevallier et al. (2011)	No	N/A	Yes	Yes	Low (5)
O'Connor (2007)	No	Yes	Yes	Yes	Moderate
Ketelaars et al. (2016)	No	Yes	Yes	Yes	Moderate
Ben-David, Mentzell, et al. (2020)	Yes	Yes	Yes	Yes	Moderate
Heikkinen et al. (2010)	No	Yes	Yes	Yes	Moderate
Tobe et al. (2016)	No	N/A	Yes	Yes (2)	Moderate
Doi et al. (2013)	No	Yes	Yes	Yes	Low (5)
Charbonneau et al. (2013)	No	N/A	No (3)	Yes	Low (5)
Brennand et al. (2011)	No	N/A	Yes	Yes	Moderate
Globerson et al. (2015)	No	Yes	Yes	Yes	Low (6)
Kleinman et al. (2001)	No	Yes	Yes	Yes	Low (5)
Stewart et al. (2013)	No	N/A	Yes	Yes	Low (6,7)
Philip et al. (2010)	No	Yes	Yes	Yes	Low (7)
Heaton et al. (2012)	No	Yes	Yes	Yes	Moderate
Kujala et al. (2005)	No	N/A	Yes	Yes	Low (5,7)
Rutherford et al. (2002)	No	N/A	Yes	Yes	Low (5)
Golan and Baron-Cohen (2006)	Yes (4)	Yes	Yes	Yes	Moderate
Golan et al. (2007)	Yes (4)	Yes	Yes	Yes	Moderate
Golan et al. (2006)	Yes (4)	Yes	Yes	Yes	Moderate

Note: (1) The full data were obtained by personal communication with the author. (2) The authors report funding from pharmaceutical companies, yet the data collected for the meta-analysis do not pertain to the medication. (3) The effect of group on performance is not available for voice identification alone, but only as a main group effect (across the three tasks). Yet as modality and group did not interact significantly, this result was deemed sufficient for the meta-analysis. (4) post hoc power analysis was conducted.Study quality by the GRADE scale (Higgins & Green, 2011). Grades range from Very Low, Low, Moderate to High level of evidence. Note, none of the studies included a randomized trial evidence (RCT), thus none of the studies received a high grade. All studies start from a grade of allocation concealment, yet blinding was not considered essential. In addition, the potential for measurement bias was minimal. (5) Indirectness of evidence: the evidence in the study was not fully compatible with the review question. (6) Imprecision: small number of participants/ small effect size. (7) Inconsistency: effect not consistent.

Using the GRADE assessment, 12 of the studies were of Moderate quality and 11 were of Low quality (see Table 2).

Assessment of risk of study bias

We conducted a risk of bias assessment for each of the 23 research papers included in the meta-analysis. The scoring system followed Higgins et al. (2011), considering that reporting requirements of experimental studies are not as rigorous as those of clinical trials. The four questions of the risk of bias assessment were: (Q1) Did the authors include a sample size justification? (Q2) If any participant data were excluded from the analysis, was a clear justification given? (Q3) Were all the outcome measures in the methods included in the results? (Q4) Were there any conflicts of interest? For each question, the score could be YES (e.g., insufficient information for judgment, clear conflict of interest), NO (e.g., appropriate use and sufficient information, no conflict of interest) or N/A (in case there were no relevant instances). All 23 studies were scored by the first and last authors. In case of a disagreement, the reviewers discussed the issue until a consensus was reached.

Statistical analysis

Meta-analyses were performed using a dedicated MS Excel workbook (van Rhee et al., 2015) for differences between independent groups–continuous data (Version 1.3). The workbook used effect size, standard error, and study size to assign an appropriate weight to each study and computes bias-adjusted standardized mean differences (Hedges' g, Confidence intervals, *CI*, and prediction intervals, *PI*). In 12 papers, *F*/*t* statistics values (with degrees of freedom) were collected for the (main) comparison of groups in each study. In 11 studies, in which *F*/*t* statistics were not provided for the subset of data relevant to our analysis, we collected means and standard deviations.

Due to the different measures, stimuli, and methodologies, a random-effects model for the meta-analyses was chosen. Positive effect sizes indicated a better performance for the TD group over the ASD-without-ID group. A 95% *PI* was calculated (Borenstein et al., 2011), giving the range in which the outcome of a future study would fall in 95% of the cases (assuming that the effect sizes are normally distributed; see van Rhee et al., 2015).

The presence of publication bias was explored by funnel plots and Egger's regression. To assess heterogeneity of studies, we used the following measures: (a) Cochran's Q test to examine the null hypothesis that all studies estimated the same effect; (b) The I^2 statistic, which shows the total variation across studies that is not due to chance, to test between-study heterogeneity. The following boundaries were used (van Rhee et al., 2015): $I^2 < 25\%$ indicating low heterogeneity and > 50% indicating high heterogeneity; and c) Tau^2 (T^2) to estimate between-study variance. The preliminary analysis was followed by subgroup analyses to reveal the source of the variance between studies. In each subgroup, we further conducted the aforementioned analyses separately.

RESULTS

Risk of bias assessment

The results of the bias assessment are displayed in Table 2. Risk of bias was high for Q1, as the majority of studies ($n = 19$) did not include a sample size calculation to inform statistical power (a-priori or post hoc). For those studies that excluded participant data, adequate justification was provided in all cases. Two studies did not provide sufficient information to confirm that results were reported for all included outcome measures, yet the data were sufficient for the meta-analysis (as detailed in Table 2). The majority of studies ($n = 22$) did not report any conflicts of interest.

Taken together, although it appears that results are at low risk of reporting bias, one cannot affirm that sample sizes in each study are sufficient to adequately detect statistically significant effects. This is of special importance for some of the studies that included a relatively small number of participants (e.g., Kujala et al., 2005, with eight participants in each group). This result forms one of the motivations to conduct a meta-analysis.

Meta-analyses

As a first step, we conducted a meta-analysis for all data sets that included either simple or complex emotions ($n = 22$, taken from 21 research papers). Note, for the preliminary analysis, the two papers that included both complex and simple emotions were excluded to avoid using the same data set of participants twice, as it might bias the aggregate effects in meta-analysis (Wood, 2008).

A visual depiction of the effect sizes (Hedges' g) in each study is presented in panel A of Figure 2, as a forest plot. To generate the forest plot, relationships were arranged from the biggest to the smallest in terms of cumulative sample size.

Figure 2a shows that about half of the studies uncovered a significant group difference, in which the *CI* lines are entirely on the positive side (>0). The cross-studies meta-analysis found a medium-sized Hedges' g effect of 0.67 ($SE = 0.13$). This effect was significant using *CI*s (95%: *CI* 0.41 to 0.91). However, one must also consider *PI*s (van Rhee et al., 2015), as pooled sample size in meta-analysis is large. *PI*s were not significant (95% *PI*: −0.33 to 1.67), suggesting the limitations of the effect. Indeed, we found general heterogeneity to be very high, Cochrane's $Q = 71.72$, $p < 0.001$, a large proportion of between-study heterogeneity, $I^2 = 70.72\%$, and relatively large distribution of true effect sizes (between-study variance), $T^2 = 0.22$, $tau = 0.46$. Following van Rhee et al. (2015), these results suggest that the analysis of all experiments grouped together in this case may not be of value and a subgroup analysis to indicate the source for this heterogeneity may be called for. We also note that grouping all studies together leads to a high publication bias, with Egger's regression $t = 2.32$ $p = 0.031$ indicating a significant funnel plot asymmetry.

Subgroup analysis

Given the high level of heterogeneity, we performed theory-driven subgroup analyses, with random effects for within subgroup weighting (tau separate for subgroups), and fixed effects for between-group weighting. Subgroup analysis was separately performed for (a) Semantic Content (low or high level) and (b) Emotional Complexity (complex or simple emotions).

Subgroup analysis for Semantic Content did not indicate significant differences between low- and high-level semantics in the tested effect (between-group sum of squares, $Q(1) = 0.01$, $p = 0.932$; within-group sum of squares, $Q(20) = 21.84$, $p = 0.349$). Importantly, I^2 did not decrease (72.01% and 70.62%, for high and low levels, respectively), indicating that semantic content classification could not reduce heterogeneity between studies.

Subgroup analysis for Emotional Complexity indicated significant differences (between-group $Q(1) = 3.97$, $p = 0.046$; within-group, $Q(20) = 23.23$, $p = 0.278$), with I^2 largely reduced for the complex emotions subgroup ($I^2 = 29.74\%$), indicating that classifying studies based on emotional complexity can decrease the heterogeneity between studies. This analysis was followed by separate

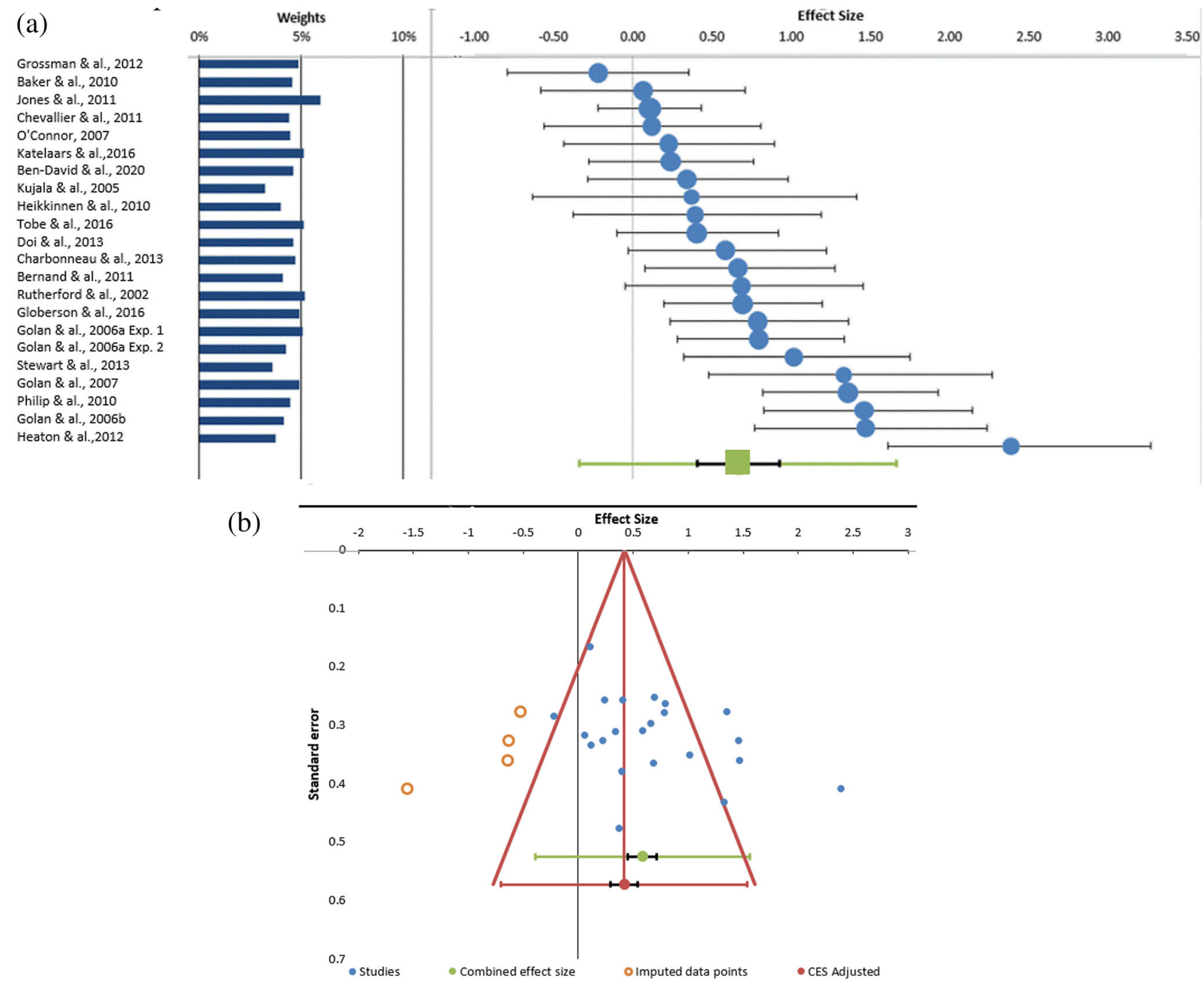

FIGURE 2 Results of the cross-studies meta-analysis. (a) Forest plot of the 22 studies, ordered by sample size (ascending). Bars represent 95% confidence intervals. The filled square represents the pooled effect size, alongside confidence (short bars) and prediction (long bars) intervals. Pooled effect's CI crosses 0, indicating the lack of predictive value for the effect. (b) Funnel plot of standard error by standard differences in the means. The asymmetric plot points to the likelihood of publication bias

meta-analyses for data pertaining to complex emotions and simple emotions, adding four data sets taken from two research papers that present both simple and complex emotions.

Note, that six of the 22 studies include adolescents (mean age younger than 19 years old). Due to the relatively small number of studies, and as all six used simple emotions, we replicated the two sub-group analyses for the remaining 16 studies that focus on adults, with highly similar results to the general analyses. Namely, subgroup analysis for Semantic Content in which I^2 did not decrease (69.51% and 45.47%, for high and low levels, respectively). Subgroup analysis for Emotional Complexity, in which I^2 largely reduced for the complex emotions subgroup (I^2 = 29.74% and 72.49% for complex and simple emotions, respectively).

Simple emotions

Figure 3a presents a forest plot of Hedges' g with 18 data sets ($n = 907$ participants) that present simple emotions. It shows that only a third of the studies report a significant group difference. Hedges' g indicates a medium effect size of 0.56 ($SE = 0.14$). This effect was significant using *CI*s (95%: *CI* 0.25 to 0.86), but, *PI*s were not significant (95% *PI*: −0.47 to 1.58). Indeed, general heterogeneity was relatively high, Cochrane's $Q = 58.71$, $p < 0.001$; a relatively large proportion of between-study heterogeneity was noted, $I^2 = 71.04\%$; and relatively large distribution of true-effect sizes (between study variance) was found, $T^2 = 0.22$, $tau = 0.46$. Figure 3b presents a funnel plot for data sets with simple emotions, suggesting a high publication bias, with Egger's regression $t = 2.46$ $p = 0.026$ indicating a significant funnel plot asymmetry.

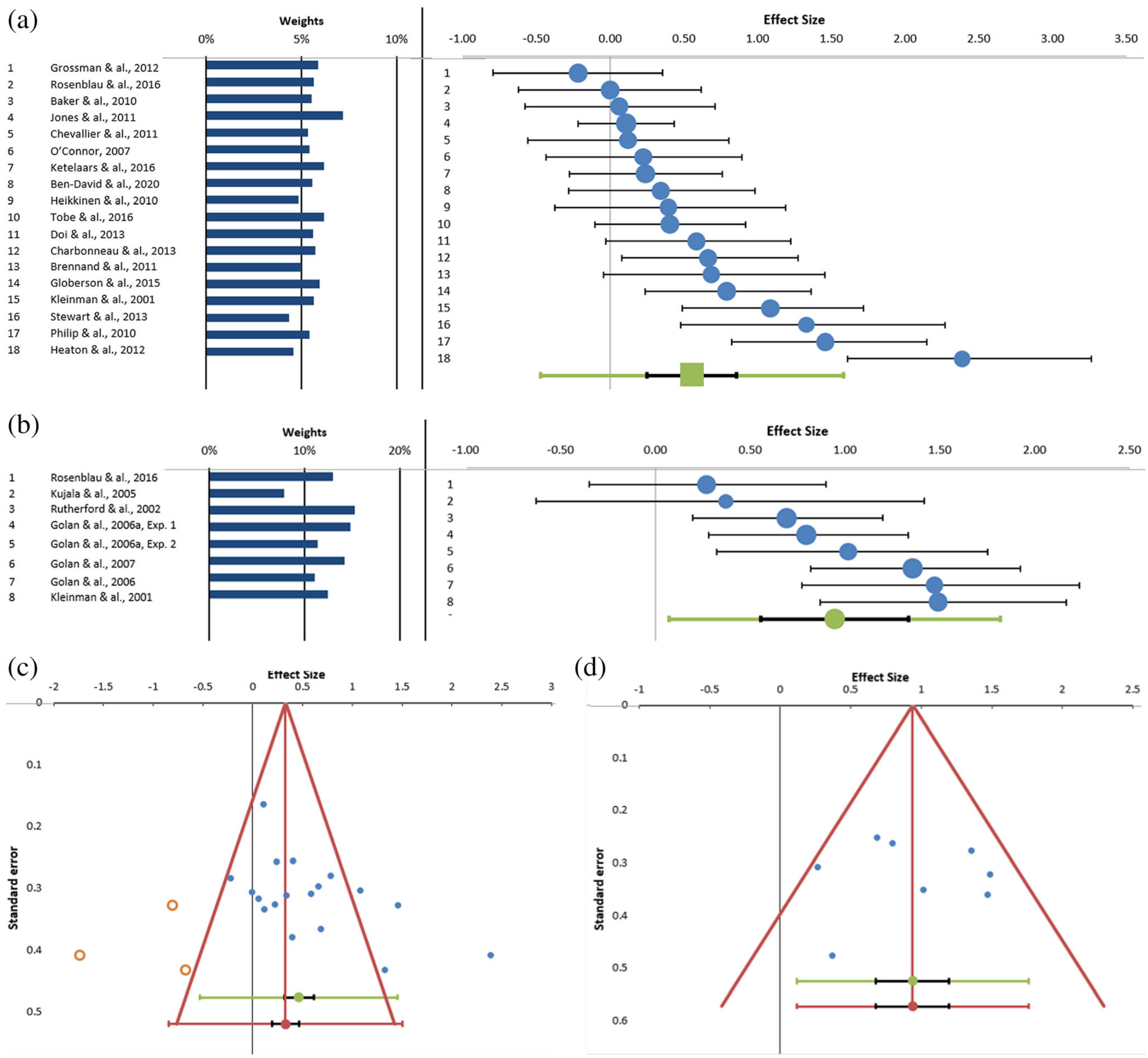

FIGURE 3 Results of the subgroup analyses: Forest plots of the 18 data sets using simple emotions (a) and 8 data sets using complex emotions (b), ordered by sample size (ascending). Bars represent 95% confidence intervals. The filled square represents the pooled effect size, alongside confidence (short bars), and prediction (long bars) intervals. Only for complex emotions (b) pooled effects' CIs do not cross 0, indicating the predictive nature of the effect. Funnel plots of standard error by standard differences in the means are taken from studies using simple emotions (c) and complex emotions (d). Panel c indicates an asymmetric plot, pointing to the high likelihood of publication bias in simple emotions. Panel d presents a symmetric plot, indicating a fairly equal distribution of the studies along the horizontal line, with little possibility of publication bias for complex emotions

In sum, it appears that when simple emotions were tested, there was no clear indication of a significant difference between ASD-without-ID and TD groups, studies were highly varied, and publication bias indicated missing studies.

Complex emotions

Figure 3c presents a forest plot of Hedges' g with eight data sets ($n = 436$ participants) that used complex emotions. It shows that the majority of data sets (six out of eight) report a significant group difference. Hedges' g indicates a large effect size of 0.94 ($SE = 0.17$). This effect was significant using both *CI*s (95%: CI 0.55 to 1.34) and *PI*s (95% *PI*: 0.07 to 1.82); general heterogeneity was relatively moderate, Cochrane's $Q = 14.84$, $p = 0.038$; a moderate proportion of between-study heterogeneity was indicated, $I^2 = 52.81\%$; and moderate distribution of true effect sizes (between-study variance) was noted, $T^2 = 0.11$, $tau = 0.33$. Figure 3d presents a funnel plot for data sets with complex emotions, suggesting no publication bias, with Egger's regression, $t = 0.05$ $p = 0.964$, indicating no funnel plot asymmetry.

In sum, when complex emotions were tested, the analysis suggested that ASD-without-ID groups performed significantly worse than did TD groups, with medium heterogeneity between studies, and no evidence for publication bias.

GENERAL DISCUSSION

In the current meta-analysis, we examined the literature on the identification of emotional prosodies for individuals with ASD-without-ID. Our meta-analysis of 26 data sets from 23 studies, with 1254 participants, points to the important role of emotional complexity in prosodic identification. In our findings, there is no sufficient evidence to suggest that individuals with ASD-without-ID differ from matched controls in the identification of *simple* prosodic emotions, such as anger, sadness, and happiness. However, the meta-analysis showed that individuals with ASD-without-ID have a significant deficit in identification of *complex* prosodic emotions, such as envy, boredom, and calmness. This confirms our initial hypothesis that individuals with ASD-without-ID successfully recruit their cognitive abilities to distinguish between different simple spoken emotions, but not between complex emotions.

In our analysis, the level of the semantic content of the stimuli used (high- vs. low-level; e.g., sentences vs. digits) was not found to have an effect on the data, contrary to our hypothesis that individuals with ASD-without-ID have difficulties in spoken emotion identification when inhibition of semantics is involved. The difference in findings between simple and complex emotions calls for a new-look on emotion processing in individuals with ASD-without-ID given their unique characteristics.

Emotion complexity

Analysis indicated that the subgroup division based on emotion complexity significantly reduced heterogeneity, both when conducted across all studies and when limited to studies focusing on adults. The separate analysis for simple emotions did not provide sufficient evidence for reduced abilities by the ASD-without-ID groups. This may hint at their ability to utilize cognitive abilities to compensate for ASD-related challenges in emotional interpretation. These results echo Loveland et al.'s (1997) suggestion that the ability to perceive emotions depends primarily on the cognitive level of the individual, rather than on the presence of ASD. Indeed, in their study, when asked to identify emotions expressed verbally, large differences were found between higher- and lower- functioning participants, regardless of ASD diagnosis. A study by Demopoulos et al. (2015) provides further support for this notion. In a sample of 25 individuals with ASD ranging in IQ from 46 (indicating middle-function intellectual level) to 136 (high intellectual level), they found a strong correlation between IQ and identification of prosodic emotions (using the Diagnostic Analysis of Nonverbal Accuracy, DANVA). In other words, in the ASD group, an increase in cognitive functioning was associated with increased identification of prosodic emotions.

In contrast to the aforementioned findings with simple emotions, the 18 data sets that used complex emotions provide strong indication for reduced performance among individuals with ASD-without-ID. This hints that identification of complex emotion may draw from advanced social and verbal skills (discrimination between nuanced emotions and naming them) that are impaired in this population. Similarly, children with ASD-without-ID were found to verbally present personal accounts of simple emotions as well as TD controls, but failed to discuss complex emotions as well as TD (Losh & Capps, 2006). In fact, impairments in social communication and in social interaction are core elements in ASD (American Psychiatric Association, 2013). ASD has been associated with impairments in implicit learning along with intact explicit learning abilities (Klinger et al., 2007; Kourkoulou et al., 2012; Nuske et al., 2013; Schneider et al., 2013; Vivanti & Rogers, 2014). Additional research has linked between ASD and impairment in implicit *social* learning, specifically (Kirchner et al., 2012). Simple emotions are more explicit in nature, whereas complex emotions call for implicit social learning. Indeed, complex emotions are context- and culture-dependent as they are belief-based (Harris, 1989), and involve advanced understanding of interpersonal situations.

Specific difficulties in implicit versus explicit social learning may explain the current findings: difficulties in identification of complex emotions along with relatively preserved identification of simple emotions. This trend may also stem from a broad impairment in Theory of Mind, conceptualized as the ability to infer others' beliefs, desires, and intentions by mentalizing these processes about others (Baron-Cohen et al., 2001; Happe & Frith, 2006). A similar distinction between first- and second-order affective theory of mind (ToM) abilities have been discussed in the obsessive compulsive disorder (OCD) literature, with findings suggesting that individuals with OCD may have preserved first-order, simple, affective ToM performance, with deficits mainly in second-order, complex, affective ToM (Liu et al., 2017; Mısır et al., 2018).

Additionally, the current results can be interpreted in light of Feldman-Barret's "Language as Context" model. The model suggests that processing language and context assists in disambiguating emotions (Feldman-Barrett et al., 2007) by relying on a consensus about categories of social reality (Adolphs et al., 2019). Accordingly, arousal and valence are perceived directly, but their naming involves linguistic and contextual factors. Simple emotions, such as anger and sadness, may be easily classified based on valence. Indeed, in studies that presented simple emotions, typically three to six highly distinctive emotions were presented. However, studies that presented complex emotions typically included a larger number of emotions that could not be easily classified based on valence and arousal. For example, one of the tested studies (Rosenblau et al., 2017) included 21 emotions: interested, frustrated, curious, passionate, contemptuous, furious, confident, proud, desperate, relieved, offended, concerned, troubled, expectant, confused, hurt, bored, in love, enthusiastic, lyrical, and shocked. These complex emotions may not be as highly distinctive as simple emotions. Discriminating between such subtle emotions demands intricate social, emotional, and linguistic faculties. Furthermore, the higher the number of options in the response set, the greater the task difficulty, as indicated by the information theory (for a discussion, see Ben-David & Algom, 2009).

The role of emotional complexity, as found in the current meta-analysis, can also resonate with the Weak Central Coherence theory (Happe', 1999; Happe & Frith, 2006). The theory suggests that a limited ability to understand context or to integrate sources of information to establish meaning underlies the difficulties of individuals with ASD. Accordingly, ASD-without-ID individuals are able to function well in relatively simple "lab tasks" (such tasks were used in the current sample of studies), but exhibit difficulties in more complex daily situations. This could also be related to the mounting evidence that about half of individuals with ASD are diagnosed with alexithymia—difficulty in identifying one own's complex emotions and describing them (Howlin & Magiati, 2017; for a meta-analysis, see Kinnaird et al., 2019), versus only 5% in TD controls. Primary alexithymia is a stable personality trait, that has been indicated to affect processing of spoken emotions in the general population (Martínez-Sánchez et al., 2002) and impair social activity (Leshem et al., 2019). Difficulty in identifying complex emotions in the current meta-analysis may reflect the higher prevalence of alexithymia in the tested population. Related to this, comorbid anxiety disorders inherent to ASD (for a meta-analysis, see Van Steensel et al., 2011) can also negatively affect spoken emotional processing.

Finally, one cannot rule out the role of auditory sensory dysfunction that might compromise the extraction of auditory emotional cues, as evidence indicate some forms of sensory disturbance for over 70% of individuals with ASD (Adamson et al., 2006). Indeed, sensory information degradation has been suggested to impair cognitive performance in visual and spoken tasks (e.g., in older adults: Ben-David & Schneider, 2009, 2010; Ben-David, Chambers, et al., 2011), and hence may specifically negatively affect processing of complex emotions.

Semantic content

Of the 23 papers collected in our meta-analysis, 16 presented high-level semantic content (sentences) that may call for integration across auditory channels (semantic and prosodic). Identification of spoken emotions is especially challenging when the emotions presented by the semantics and the prosody do not match (i.e., the identification of irony, Ben-David, van Lieshout, & Leszcz, 2011; Ben-David et al., 2013). For example, Ben-David, Ben-Itzchak, et al. (2020) presented stimuli like "I won the Lottery today" spoken with sad prosody, and asked participants to focus on the emotional prosodic content (in this example, sadness), while ignoring the emotional semantic content (happiness). Sub-group analysis based on semantic content level was not found to reduce heterogeneity between studies. In other words, the need to integrate across auditory channels, or to inhibit the semantic channel, was not found to generate a difference in spoken emotion identification between ASD-without-ID and TD groups (for a discussion of the effect of semantic content on test performance, see Ben-David & Icht, 2017; Icht & Ben-David, 2015). These findings may suggest inhibition as a preserved skill for individuals with ASD-without-ID (for related evidence in the visual modality, see Brady et al., 2017; Geurts et al., 2009).

Limitations

Due to the nature of meta-analysis procedure, there are limitations related to the variance of tools, measures and stimuli used in the selected studies. Clearly, the identification of emotional cues in speech can be measured through a variety of methods. We addressed two main sources of variance in the analysis: emotional complexity and semantic content. However, there are more sources that could have been addressed. These include the age of participant (see Peppe et al., 2007), the language used, cultural differences (see Icht & Ben-David, 2014, 2018), and the level of cognitive ability (70–84; ≥85 IQ scores). It is also possible that the effect of such variables will be manifested in an interaction between two or more of them. This calls for further studies of simple emotions, targeted at testing these possible factors.

The studies collected in the current meta-analysis used different measures to gauge ASD, leading to possibly different experimental groups. Moreover, the information about the general cognitive levels (e.g., via IQ scores) for both clinical and control groups was missing in many of the studies. To somewhat offset this possible bias, we were careful in selecting only studies that adhered to accepted and agreed criteria for ASD diagnosis. We note that the papers selected for review vary in their quality of evidence (as assessed by the GRADE system) from Low to Moderate levels and rarely used a power analysis for sample size selection. Indeed, more research is needed in this field. Finally, the meta-analysis was focused on individuals with ASD-without-ID. Clearly, the current analysis cannot point to the specific role of cognitive functioning (i.e., presence of ID) in identification of spoken emotions for individuals with ASD, as we did not conduct a direct comparison with a collection of studies focusing on individuals with ASD-with-ID. However, evidence in the literature suggest that a large percentage of individuals with ASD-with-ID does not develop complete communication and linguistic skills (e.g., see Maljaars et al., 2011), impairing their ability to perform verbal tasks in general. Clearly, the current findings cannot be generalized to all individuals with ASD, given the high level of heterogeneity. Future reviewers may wish to focus on individuals with ASD-with-ID.

Conclusions and clinical implications

To conclude, spoken emotion recognition is a fundamental element in emotional and social understanding. Individuals with ASD typically show difficulties in recognizing emotions and mental states in others (Golan et al., 2006). However, the present meta-analysis could not find sufficient evidence to suggest that adults with ASD-without-ID identify basic emotions presented via the auditory modality differently than do age-matched TD peers. Educational and social support programs may rely on the possibly intact abilities of individuals with ASD-without-ID in learning social skills, improving social interactions and building personal relationships. The clear evidence that indicates deficits in processing complex emotions points to the need for intervention programs to target this ability, as better understanding of the meaning of spoken language may enhance social-communication skills for individuals with ASD-without-ID. Recently, in response to COVID-19 social restrictions, a remote adaptation (an online version) of a spoken emotion identification tool, iT-RES (internet Test for Rating Emotions in Speech, Ben-David et al., 2020), has been validated. We suggest using this tele-health tool to better portray idiosyncratic spoken emotion processing performance for individuals with ASD-without-ID.

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CONFLICT OF INTEREST

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

ETHICS STATEMENT

This meta-analysis was approved by an Institutional Ethics Committee.

AUTHOR CONTRIBUTION

All four authors were involved in the development of the research idea, wrote the manuscript together, discussed the results, their analysis and their implications and commented on the manuscript in all stages. Boaz M. Ben-David designed the study and analyzed the data. Michal Icht was responsible for literature search and assessment. Gil Zukerman and Esther Ben-Itzchak provided interpretive analysis and critical revisions. All four authors approved the manuscript.

ORCID

Michal Icht https://orcid.org/0000-0002-9228-309X
Gil Zukerman https://orcid.org/0000-0001-5837-1283
Esther Ben-Itzchak https://orcid.org/0000-0002-3167-5006
Boaz M. Ben-David https://orcid.org/0000-0002-0392-962X

ENDNOTE

[i]Note, the diagnosis of AS overlaps that of ASD-without-ID (Doi et al., 2013), but is not necessarily equivalent to ASD-without-ID (Klin & Volkmar, 1995). AS is a previously defined developmental disorder that was considered a subcategory of Pervasive Developmental Disorder (PDD; DSM IV, American Psychiatric Association, 1994), with relatively preserved language and cognitive abilities, but reduced social cognition.

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