

The effects of intervention on the comprehension of irony and on hemispheric processing of irony in adults with ASD



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ABSTRACT

Individuals with autism spectrum disorders (ASD) experience difficulty in comprehending figurative language in general and irony in particular. The current study measured the effectiveness of a short-term intervention in enhancing the comprehension of irony. Twenty-nine adults with ASD and 22 typically developing (TD) adults participated in the study. Participants with ASD were randomly assigned to a study (intervention) or control (passive intervention) group. TD participants were also assigned to a passive intervention control group. The intervention improved comprehension of irony in the ASD group. Furthermore, responses to ironic and literal targets were similar within each hemisphere prior to the intervention within the ASD study group, but after the intervention responses lateralized to the right. Thus, following the intervention, participants with ASD demonstrated a pattern of hemispheric processing of ironic target words that resembled the pattern seen in the TD group prior to the intervention. Our findings suggest that an intervention that focuses on comprehension of irony improves performance of adults with ASD and affects the pattern of hemispheric processing of irony.

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1. Introduction

Irony is quite common in everyday discourse, consisting of 8% of all conversations among college students (Gibbs, 2000), and frequent in written online blogs (Whalen et al., 2013). It allows the speaker to express humor (Roberts and Kreuz, 1994) as well as criticism (Dews and Winner, 1995), and is important in creating social bonds (Clark and Gerrig, 1984). Irony is often conveyed as the opposite message of the literal or salient meaning of words, and its understanding requires sophisticated reasoning of the intended interpretation (Gibbs et al., 2014), as well as the ability to figure out the pragmatic or functional aspects of the communicative act (Filippova and Astington, 2008; Pexman et al., 2011). Thus, in order to fully appreciate irony, one must rely on a wide range of cues that include attention not only to the speech utterance but also to tone of voice, facial expressions, and the speaker's intentions (Hancock, 2004; Pexman, 2008).

Research suggests that individuals with autism spectrum disorders (ASD) experience difficulty in comprehending figurative language in general (Abrahamsen and Smith, 2000; Mackay and Shaw, 2004; Rundblad and Annaz, 2010) and irony in particular

(Colich et al., 2012; Pexman et al., 2011), and tend to interpret such language literally. An alternative approach suggests that the difficulty in processing figurative language in ASD may be associated with the novelty of the stimuli rather than its non-literality (Kasirer and Mashal, 2014; Giora et al., 2012; Gold and Faust, 2012). Giora et al. (2012) examined the ability of young adults with Asperger syndrome and TD participants to judge the meaningfulness of familiar metaphors, familiar literals expressions, novel metaphors, novel literals expressions and meaningless sentences. TD participants outperformed the AS group, but nonetheless, both groups exhibit a similar patterns of linguistic behavior to the familiar stimuli's as they were less complex as compared to novel ones. Thus, it seems that it is easier for ASD to refer to familiar stimuli regardless of its metaphoricity (i.e. familiar metaphors and familiar literals expressions).

Most studies that focused on irony in ASD have examined children and adolescents (Mackay and Shaw, 2004; Pexman et al., 2011; Wang et al., 2006) and only a few included adults (Martin and McDonald, 2003; Saban-Bezael and Mashal, 2015; Williams et al., 2013). It is yet unclear whether people with ASD have a general deficit in language comprehension or a specific difficulty in comprehending figurative language. Indeed, Gernsbacher and Pripas-Kapit (2012) argue that people with ASD perform more poorly on both literal and figurative language tasks, possibly due to a general language disability. However, recent studies have shown that there is no major impairment in comprehension of

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figurative language in ASD, and participants perform above chance (Giora et al., 2012; Kasirer and Mashal, 2014; Olofson et al., 2014; Saban-Bezelel and Mashal, 2015).

Several intervention studies that aimed at improving the comprehension of figurative language in ASD have been conducted, focusing on idioms (Abrahamsen and Smith, 2000; Whyte et al., 2013), metaphors (Mashal and Kasirer, 2011; Melogno and Pinto, 2014), and sarcasm (Persicke et al., 2013). Melogno and Pinto (2014) describe intervention activities that included explicit teaching through visual aids as well as through discussions of semantic features in metaphors and metonymies. Persicke et al. (2013) used rule instruction, video clips, and explicit training across multiple exemplars to teach the detection of sarcastic statements and ensuing responses. The three children who participated in this study benefited from the intervention, as seen in their post-intervention performance with trained as well as with novel exemplars. To the best of our knowledge, no intervention has been conducted in adults with ASD, despite the general agreement that some comprehension difficulties persist into adulthood (Gold and Faust, 2010; Kasirer and Mashal, 2014; Martin and McDonald, 2003; Williams et al., 2013).

The current study examined an intervention whose aim was to improve comprehension of irony in adults with ASD. Beyond testing changes in comprehension following the intervention, we also tested changes in the pattern of hemispheric processing of irony. It has been shown that the right hemisphere plays an important role in the processing of many types of figurative language, including comprehension of humor, sarcasm, novel metaphors, indirect requests, and emotional prosody (Briner et al., 2011; Coulson and Severens, 2007; Mashal et al., 2007; Mitchell and Crow, 2005). There is also evidence that ironic statements are processed in the right hemisphere (Eviatar and Just, 2006; Giora et al., 2000; Shibata et al., 2010).

According to the fine vs. coarse semantic coding theory (Beeman, 1998), the left hemisphere (LH) engages in fine semantic coding, in which a single interpretation of a word, its dominant semantic features, as well as several of its close associates are activated. In contrast, the right hemisphere (RH) engages in coarse semantic coding, in which distinct semantic relations of words or multiple interpretations of ambiguous words are activated (Jung-Beeman and Bowden, 2000; Jung-Beeman et al., 2000). Since the figurative meaning of an unfamiliar utterance is usually more semantically distant than its literal interpretation, this model predicts that the RH will be more apt for the interpretation of figurative language in general and for the interpretation of irony in particular.

Giora (1997, 1999, 2003) introduced the graded salience hypothesis, according to which stimuli's coded, salient meanings enjoy priority, regardless of degree of literality or contextual fit. Salience, though, is a matter of degree and it is determined primarily by frequency of exposure, familiarity with the meaning in question and its prototypicality (Giora, 1999, 2002; Giora et al., 2007, 1998; Giora and Fein, 1999). A linguistic stimulus that is salient will be retrieved directly from the mental lexicon (Giora and Fein, 1999). Additionally, according to the graded salience hypothesis, the LH will be involved in processing salient meanings whereas the RH will be involved in processing novel, noncoded, i.e., non-salient meanings and interpretations.

Consistent with these theoretical frameworks, both behavioral and neuroimaging evidence collected from typically developing (TD) individuals point to RH specialization in processing of non-salient interpretations of figurative language (Kasparian, 2013; Schmidt et al., 2007), including novel metaphors (Faust and Mashal, 2007; Mashal et al., 2005, 2007), the non-salient literal interpretations of idioms (Mashal et al., 2008), as well as the non-salient interpretations of ironic sentences (Eviatar and Just, 2006;

Shibata et al., 2010). These findings suggest that familiar utterances with salient (often literal) meanings activate fine semantic coding mechanisms in the LH. In contrast, unfamiliar utterances with non-salient ironic interpretations rely on coarse processing that takes place within the RH.

Mashal and Faust (2009) used the divided visual field (DVF) paradigm to show hemispheric changes in TD adults during repeated exposure to novel metaphors. Participants were presented with word pairs and were asked to perform a semantic judgment task. At first exposure the RH was better than the LH at processing novel but not conventional metaphoric expressions. Participants performed the same experiment again after a 30 min delay, at which time they were both faster and more accurate in responding to metaphoric expressions, and demonstrated a shift from right lateralization to equal involvement of both hemispheres. These findings point to changes in hemispheric involvement once expressions become more familiar. In the current study we examine whether such shifts also occur in adults with ASD following an intervention that familiarize them with ironic expressions.

Unlike findings in the TD population, no clear rightward asymmetry has been reported in individuals with ASD in processing novel metaphors (Gold and Faust, 2010, 2012) or irony (Colich et al., 2012; Saban-Bezelel and Mashal, 2015). Gold and Faust (2010) demonstrated a RH advantage in processing of non-salient metaphoric interpretations in TD participants but no RH advantage was observed in adults with Asperger syndrome. Similarly, Colich et al. (2012) found that children and adolescents with ASD showed bilateral activation during processing of ironic versus sincere remarks. Saban-Bezelel and Mashal (2015) reported that adults with ASD processed ironic stimuli bilaterally, unlike TD adults who showed a RH advantage. These findings suggest that brain lateralization is atypical in adults with ASD, and that the RH might be less functional in processing figurative language in ASD (Ellis et al., 1994; McKelvey et al., 1995).

Here we examined a short intervention whose main aim was to improve comprehension of irony in ASD. Adults with ASD who participated in the intervention were compared to adults with ASD who did not participate in the intervention as well as to TD adults. These ASD and TD control groups participated in a passive intervention. We assumed that TD participants would exhibit a LH advantage in processing salient literal meanings of familiar stimuli and a RH advantage in processing non-salient ironic interpretations of non-lexicalized ironic stimuli. We also expected that familiarization would lead to the disappearance of the RH advantage in the TD group. Lower overall comprehension was predicted in adults with ASD, with bilateral hemispheric processing of ironic expressions. We further hypothesized that the intervention would lead to changes in comprehension and in hemispheric processing of irony, relative to pre-intervention as well as relative to individuals with ASD who participate in the passive intervention.

2. Method

The study consisted of four stages: (1) screening tests; (2) pre-intervention testing; (3) intervention; (4) post-intervention testing.

2.1. Participants

Fifty-one native Hebrew speakers participated in the study, 29 adults with ASD (9 women) and 22 TD adults (9 women). Of the 29 participants with ASD, 16 (7 women) participated in the intervention (study group) and 13 (2 women) were assigned to the ASD control group. Adults with ASD that were recruited to the study were randomly assigned to the study and the control groups within the order of their enrollment. Some participants with ASD and all TD participants also participated in our previous study of hemispheric processing of idioms and irony (Saban-Bezelel and Mashal, 2015). We emphasize that their participation in our previous study did not influence their performance in the current study as our

previous study constitutes the first two stages (i.e., hemispheric processing of idioms and irony) of the current study. Thus, participants in the previous study were not exposed to additional content that could have influenced their performance in the current study. There was no statistical difference in gender distribution across the three groups, $\chi^2(2)=3.06, p=.22$. All participants were right-handed, had intact or corrected-to-normal vision, reported no neurological problems, and all completed at least 12 years of schooling. Participants with ASD had been diagnosed by an independent psychiatrist as having PDD-NOS (31%, $n=9$) or Asperger syndrome (69%, $n=20$), according to the DSM-IV-TR criteria (American Psychiatric Association, 2000). In light of the new classification that now appears in the DSM-5, we refer to the entire group with the term ASD. To confirm the clinical psychiatric diagnosis, participants were also assessed with the autism-spectrum quotient questionnaire (Baron-Cohen et al., 2001), scoring above 26 ($M=29.20, SD=4.06$). This score is clinically acceptable as a cutoff for ASD (Golan et al., 2009; Gold and Faust, 2010; Kurita et al., 2005; Woodbury-Smith et al., 2005). Prior to their participation in the study, all participants signed an informed consent. Individuals with ASD were recruited from community centers and local organizations that serve adults with ASD, and were paid for their participation. Participant recruitment adhered to institutional research guidelines.

2.2. Screening tests

All participants were screened with the test of non-verbal intelligence (TONI-3, Brown et al., 1997) and the vocabulary subtest from the Wechsler Adult Intelligence Scale (WAIS-III, Wechsler, 2001). As can be seen in Table 1, groups were matched in non-verbal IQ as well as in vocabulary scores. The two ASD groups were also matched in both non-verbal IQ, $t(27)=.81, p=.43$, and in vocabulary, $t(27)=.63, p=.54$.

2.3. Pre-intervention testing

Participants completed an irony questionnaire and a computerized test. Prior to intervention and with its completion, participants filled out the irony questionnaire. The questionnaire was handed to the participants by whoever led the intervention (see below). The behavioral paradigm which examined hemispheric processing was conducted by the first author to all participants prior to intervention and after the intervention.

2.3.1. Irony questionnaire

Participants completed a questionnaire that tested their comprehension of irony with no time limitation. The questionnaire included 15 short passages, 10 with ironic interpretation and 5 with literal interpretation, presented in a pseudo-random order. After reading each passage, participants were asked an open question.

2.3.1.1. Stimuli. The authors constructed 84 short passages in which the final word was missing. In order to select an ironic or literal ending to the paragraphs 20 judges (age 18–35), who did not participate in the experimental tasks, were asked to write down a single word that could end each of the 84 passages either literally or ironically. Words that were used by at least 80% of the judges were chosen for the study. Meaningless target words were created by the authors. Paragraph length and target words of all three types were matched for length in addition target words were matched for familiarity. Next, passages were presented along with their selected target words to 20 additional judges (age 18–35), who were asked to indicate whether the paragraph conveys a literal, ironic or meaningless interpretation. Only passages that reached high consent among judges (above 90%) were selected for the study (see Saban-Bezalel and Mashal (2015)).

For example: “Sigal and Daphne rode a very crowded bus and had to stand during the entire ride. When they got off the bus, Sigal said: “Riding public transportation is a real treat. What did Sigal think about public transportation?” Participants were asked to write their answers and each correct answer received 1 point (maximum 10 points for ironic passages; maximum 5 points for literal passages). The 15 passages were chosen randomly from this pool of passages (also used by Saban-Bezalel and Mashal (2015)).

Table 1
Demographic characteristics, by group.

	ASD study group (1)		ASD control group (2)		TD (3)				Scheffe
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i>	<i>p</i>	
Age	28.16	6.19	24.36	4.12	27.45	3.94	2.51	.09	1=2=3
TONI-3	37.06	4.46	35.31	7.17	39.14	3.98	2.39	.10	1=2=3
Vocabulary	44.56	7.17	42.69	8.92	47.95	4.20	2.74	.08	1=2=3

2.3.2. Hemispheric processing

The divided visual field paradigm (DVF) was used to examine hemispheric lateralization. This paradigm is based on the anatomy of the visual system in which stimuli that are presented to one visual field are transmitted to the opposite hemisphere only, thus making it possible to stimulate each hemisphere separately. The current DVF experiment is identical to the experiment described by Saban-Bezalel and Mashal (2015).

2.4. Stimuli

The DVF experiment included 28 ironic passages, 28 literal passages, and 28 meaningless passages. Each passage was completed with a different interpretation (i.e. ironic, literal or meaningless). For example, the passage was: “Exhausted after a long day at work, David planned to go to bed early. Just as he was ready for bed, he heard a knock on the front door. David opened the door and saw that some friends came by for a visit. David said: “The timing is...”. The ironic ending was “perfect”. Another passage was: “Dalia’s husband was aboard. Due to his return she prepared a gourmet meal for him. Dalia was very disappointed when he called and told her the flight was...”. The literal ending was “canceled”. Words of all three types were matched for length and frequency (based on Linzen (2009)). For a detailed description of stimuli construction see Saban-Bezalel and Mashal (2015).

2.5. Procedure

Participants sat in front of a computer screen, at a viewing distance of 60 cm, and placed two right-hand fingers between the key that denoted that the passage was meaningful and the key that denoted that the passage was meaningless. A fixation point appeared at the center of the screen for 2000 ms, and once it disappeared the passage appeared at the center of the screen for 2500–7000 ms, depending on its number of words (presentation time was determined in the pilot study). Next, a fixation point was presented for 300 ms, after which the target word appeared and remained on the screen for 180 ms. Target words were presented at 2.8° to the right or to the left of the fixation point, so that processing took place either in the RVF/LH or in the LVF/RH. The fixation point remained on the screen until the target word disappeared. Participants were instructed to read the passage silently, focus on the fixation point without moving their eyes, and then indicate as accurately and as quickly as possible whether the passage had a meaningful interpretation by pressing the designated key. The session began with a practice list, consisting of 9 trials that were not used in the experiment. Passages were presented in a random order, with a short break offered after completion of half of the experimental trials.

2.6. Intervention

2.6.1. Stimuli

The intervention included video clips, as well as short stories and comic strips with an open ending. Twenty video clips were cut out from movies and TV shows, each lasting 30–60 s. Each clip displayed a situation that ended with an ironic expression. Thirteen TD adults (ages 18–35), who did not participate in the experimental tasks, judged whether these clips were ironic. Only clips that were judged as ironic by at least 80% of raters were included in the intervention. The mean percentage of judges who rated the clips as ironic was 92.5% ($SD=7.10$).

Five short stories and 13 comic strips were constructed by the authors and were used to practice ironic situations during the intervention. We used material developed by the Center of Educational Technology (specialcomics.cet.ac.il) to construct these stories and comic strips. For example, “Dan wanted to lose weight and consulted a nutritionist. The nutritionist recommended an appropriate diet and suggested that he begins exercising. Dan likes eating and hates physical activity, and so he did not follow these recommendations. The nutritionist was frustrated with Dan’s progression. On their last meeting, she weighed Dan and saw no change. She then said: “Wonderful Dan, keep it up!”.

2.6.2. Procedure

The intervention was administered to small groups of 3–5 members each, in sessions of 30–45 min once a week for five consecutive weeks. One speech and language pathologist and six teachers (five females, age range 25–40) with prior experience with ASD led group discussions. The speech and language pathologist was also involved in designing the intervention and in training the teachers.

Appendix provides a detailed description of the content of each session. As can be seen in the Appendix, the first session introduced figurative language in general and irony in particular, with a focus on its usage in social context. Cues to the analysis of irony were presented and participants were asked to identify irony in video clips. Each of the next four sessions began with an analysis of video clips. Each session involved four different films (with a total of 20 clips over the entire intervention). In the second part of the session participants were asked to create verbal irony through the short stories and comic strips that had been constructed by the authors (see Appendix A for more details).

Individuals in the ASD control group and in the TD group did not participate in the intervention. Instead, they had a passive intervention during which they watched the same video clips that were used in the intervention, and were asked to rate each clip on a 5-point scale ranging from 1=not enjoyable to 5=highly enjoyable as well as on a 5-point scale ranging from 1=easy to understand to 5=difficult to understand. The speech and language pathologist who administered the intervention also led video watching in the control groups. Administration was done in small groups as in the intervention. Videos were rated in a single session following the DVF experiment.

2.7. Post-intervention testing

Following the intervention, participants completed the same irony questionnaire as well as the same hemispheric experiment that were administered prior to the intervention.

All intervention leaders were trained together by the experimenter. Following each session, the intervention leaders filled a form in which they reported on each participant, commenting on attention, comprehension, and involvement. In addition, the experimenter randomly observed the intervention sessions to ensure that the sessions are delivered properly.

3. Results

3.1. Irony questionnaire

Performance on the questionnaire was at ceiling in the TD group and thus results were analyzed only for participants with ASD. Table 2 presents the percent of correct responses on the irony questionnaire. A three-way ANOVA was conducted with time (before and after) and passage type (ironic and literal) as within-subject factors, and group (ASD study and ASD control) as a between-subject factor.

A significant main effect of passage type was found, $F(1, 24)=10.18$, $p=.00$, $\eta^2=.30$, with less accurate responses to ironic passages ($M=88.48\%$, $SD=17.68$) than to literal passages ($M=98.39\%$, $SD=7.58$). No significant main effects of either time, $F(1, 24)=2.16$, $p=.15$, $\eta^2=.08$, or group, $F(1, 24)=1.55$, $p=.23$, $\eta^2=.06$, were found.

No two-way interactions were significant: time \times passage type, $F(1, 24)=1.47$, $p=.24$, $\eta^2=.06$, time \times group, $F(1, 24)=3.59$, $p=.07$, $\eta^2=.13$, passage type \times group, $F(1, 24)=1.31$, $p=.26$, $\eta^2=.05$.

The three-way interaction of time \times passage type \times group was significant, $F(1, 24)=4.95$, $p=.04$, $\eta^2=.17$. A Bonferroni post-hoc analysis indicated that the ASD study group was less accurate on ironic relative to literal passages before the intervention ($p=.02$) but not after the intervention ($p=.78$). The ASD control group was significantly less accurate on ironic passages than on literal passages both before ($p=.05$) and after the passive intervention ($p=.01$) (Fig. 1).

3.2. Hemispheric processing

Two $2 \times 2 \times 2 \times 3$ repeated-measures analyses of variance (ANOVA) were conducted, with time (before and after the intervention), visual field (right and left), and target word (ironic and literal) as the within-subject factors, and group (ASD study group, ASD control group, and TD) as the between-subject factor. One analysis was conducted for reaction times (RTs) and another for

Table 2
Mean percent of correct responses on the irony questionnaire by time and passage type, separately for each ASD group.

Group	Pre-intervention				Post-intervention			
	Literal		Ironic		Literal		Ironic	
	M	SD	M	SD	M	SD	M	SD
ASD study	100.00	.00	86.87	20.56	100.00	.00	98.75	3.42
ASD control	99.00	3.16	85.50	22.42	100.00	.00	83.00	29.08

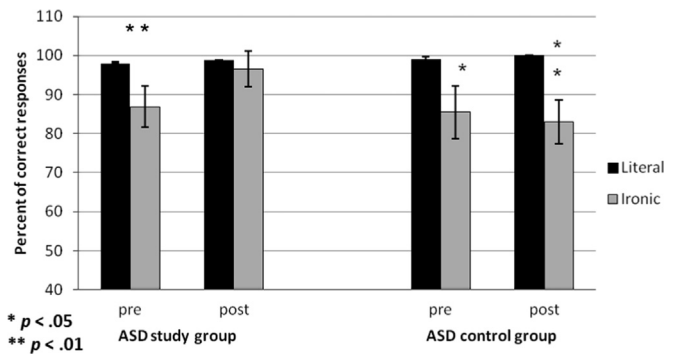


Fig. 1. Mean percent of correct responses (SE) on the irony questionnaire by time and passage type, separately for each ASD group.

accuracy rate.

3.2.1. RT analysis

The analysis of reaction times revealed a significant main effect of time, $F(1, 48)=57.58$, $p=.00$, $\eta^2=.54$, indicating that responses to stimuli presented on the second administration ($M=737.66$, $SD=221.57$) were significantly faster than responses to stimuli presented on the first administration ($M=916.46$, $SD=202.43$). The main effect of visual field was also significant, $F(1, 48)=18.45$, $p=.00$, $\eta^2=.28$, with faster responses to stimuli presented to the LVF/RH ($M=803.58$, $SD=198.97$) than to stimuli presented to the RVF/LH ($M=850.53$, $SD=203.71$). Furthermore, a significant main effect of group was found, $F(2, 48)=6.81$, $p=.00$, $\eta^2=.22$. A Scheffe post-hoc analysis indicated that TD participants responded more quickly ($M=734.65$, $SD=97.59$) than did individuals with ASD in the study group ($M=949.61$, $SD=215.28$) ($p<.01$). No significant difference was observed between RT in the TD group and RT in the ASD control group ($M=832.61$, $SD=226.22$) ($p=.30$), and between the ASD study group and the ASD control group ($p=.22$). The main effect of target word was not significant, $F(1, 48)=.4$, $p=.85$. See Table 3 for raw data.

The two-way interaction of time \times target word was significant, $F(1, 48)=5.93$, $p=.02$, $\eta^2=.11$. A Bonferroni post-hoc analysis revealed that there was no significant difference in RT between the two types of target words prior to the intervention ($p=.19$) as well as after the intervention ($p=.07$). The two-way interaction of visual field \times target word was significant, $F(1, 48)=6.16$, $p=.02$, $\eta^2=.11$. A Bonferroni post-hoc analysis indicated that there was no significant difference in RT in response to the two types of target words within the LVF/RH ($p=.06$), and the same was true for the RVF/LH ($p=.17$). The two-way interactions of time \times visual field, $F(1, 48)=.02$, $p=.88$, $\eta^2=.00$, time \times group, $F(2, 48)=.65$, $p=.52$, $\eta^2=.03$, visual field \times group, $F(2, 48)=1.77$, $p=.18$, $\eta^2=.07$, and target word \times group, $F(2, 48)=.36$, $p=.70$, $\eta^2=.01$, were not significant.

The three-way interaction of time \times target word \times group was significant, $F(2, 48)=3.69$, $p=.03$, $\eta^2=.13$. A Bonferroni post-hoc analysis indicated that within the ASD study group, RT to the two types of target words did not differ before the intervention ($p=.06$), but after the intervention, responses to ironic target words were significantly faster than responses to literal target words ($p=.01$). Within the ASD control group the pattern of responses was similar before ($p=.87$) and after the passive intervention ($p=.50$). Within the TD group there were no significant differences in RT for the two types of target words either before ($p=.83$) or after the passive intervention ($p=.16$). The three-way interactions of time \times visual field \times target word, $F(1, 48)=.98$, $p=.33$, $\eta^2=.02$, time \times visual field \times group, $F(2, 48)=.20$, $p=.82$, $\eta^2=.01$, and visual field \times target word \times group, $F(2, 48)=.33$, ns, $\eta^2=.01$, were not significant.

Table 3
Mean (and SDs) for RTs by time, visual field, word type, for each group separately.

Group	Pre-intervention				Post-intervention			
	Literal		Ironic		Literal		Ironic	
	RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH
ASD study	1034(207.20)	973(222.50)	1093(213.40)	1018(278.30)	917(269.20)	887(282.60)	810(266)	788(249.60)
ASD control	925(234.40)	889(217.80)	951(265.60)	872(260.50)	776(235.50)	717(253.90)	887(298/22)	720(255.20)
TD	811(143.10)	861(144.40)	890(217.60)	792(151.80)	656(116.65)	635(121.10)	625(128.75)	607(125.70)

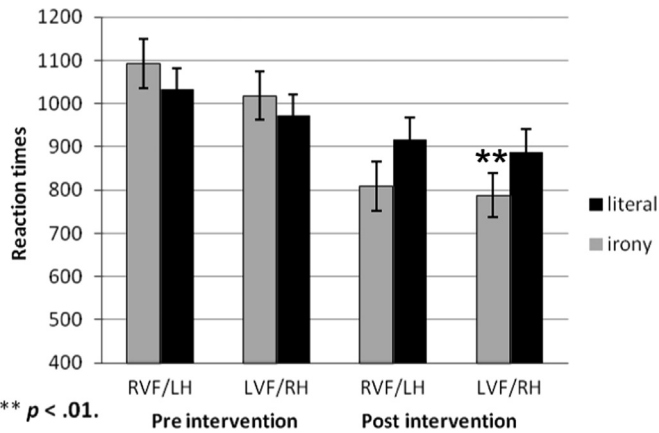


Fig. 2. Mean RTs (SE) in the ASD study group, by time, visual field, and target word.

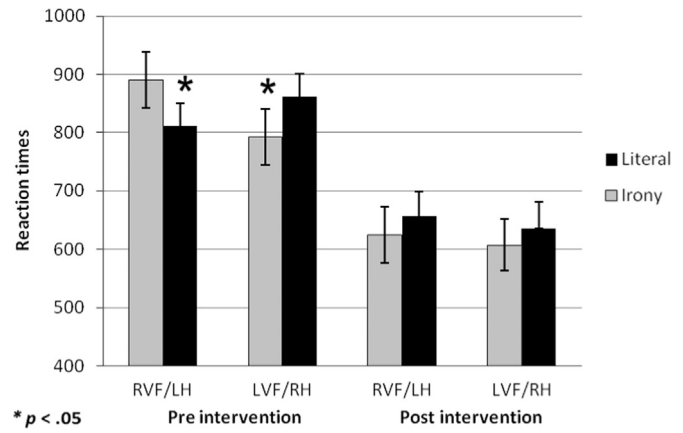


Fig. 4. Mean RTs (SE) in the TD group, by time, visual field, and target word.

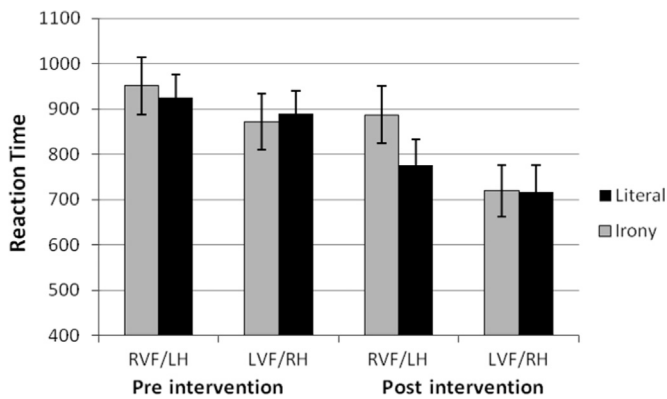


Fig. 3. Mean RTs (SE) in the ASD control group, by time, visual field, and target word.

The four-way interaction of time \times visual field \times target word \times group was significant, $F(2, 48)=3.18, p=.05, \eta^2=.12$. A Bonferroni post-hoc analysis of RT in the ASD study group showed no significant difference between the two types of target words prior to the intervention ($p=.18$) in the LVF/RH, but a significant difference after the intervention ($p < .01$), with faster responses to ironic target words than to literal target words. No significant differences between the two types of target words were found in the RVF/LH, either before ($p=.17$) or after the intervention ($p=.32$) (see Fig. 2). In the ASD control group, there was no significant difference between the two types of target words in either visual field before the passive intervention (LVF/RH: $p=.66$, RVF/LH: $p=.58$) as well as after the passive intervention (LVF/RH: $p=.94$, RVF/LH: $p=.32$) (see Fig. 3). The results of the TD group indicated significantly faster responses to ironic target words than to literal

target words prior to the passive intervention when stimuli were presented to the LVF/RH ($p=.02$) as opposed to significantly faster responses to literal target words than to ironic target words when stimuli were presented to the RVF/LH ($p=.03$). No significant differences between the two types of target words were observed within the TD group after the passive intervention, regardless of visual field ($p=.34$ in the LVF/RH and $p=.23$ in the RVF/LH) (see Fig. 4).

Thus, there was no difference in RT between the ironic and the literal stimuli within each hemisphere prior to the intervention in both ASD groups. After the intervention the ASD study group demonstrated faster responses for ironic targets relative to literal target words when stimuli were presented to the LVF/RH. Such changes were not observed in the ASD control group as no difference in RT between the ironic and the literal stimuli within each hemisphere were found after the passive intervention. TD participants demonstrated faster responses to ironic than to literal target words prior to the passive intervention in the LVF/RH, with no differences between the two types of target words after the passive intervention.

3.2.2. Accuracy analysis

A $2 \times 2 \times 2 \times 3$ ANOVA of the percentage of correct responses revealed a significant main effect of time, $F(1, 48)=14.05, p=.00, \eta^2=.23$, indicating greater accuracy after the intervention ($M=85.82\%, SD=12.80$) than before the intervention ($M=80.37\%, SD=12.67$). The main effect of visual field was significant, $F(1, 48)=6.50, p=.01, \eta^2=.12$, with more accurate responses to stimuli presented to the LVF/RH ($M=84.18\%, SD=11.83$) than to stimuli presented to the RVF/LH ($M=82.02\%, SD=12.28$). The main effect of target word was also significant, $F(1, 48)=23.70, p=.00, \eta^2=.33$, indicating that responses to ironic target words ($M=77.78\%, SD=19.01$) were less accurate than were responses to literal target

Table 4
Mean (and SDs) for accuracy rate (% correct) by time, visual field, target word, for each group separately.

Group	Pre-intervention				Post-intervention			
	Literal		Ironic		Literal		Ironic	
	RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH
ASD study	82.6(13.3)	86.2(7.6)	62.2(21.3)	68.0 (27)	88.0(11)	87.0(10)	82.0(20)	82.0(22)
ASD control	85.0(10.3)	85.0(14)	66.0(25)	70.0(26.3)	84.0(12)	87.0(8)	66.0(29)	72.0(29)
TD	93.0(6)	92.0(7)	77.0(18)	86.0(16)	94.0(6)	90.0(7)	90.0(7)	92.0(9)

words ($M=88.42\%$, $SD=7.31$). Furthermore, a significant main effect of group was found, $F(2, 48)=6.62$, $p=.00$, $\eta^2=.22$. A Scheffe post-hoc analysis indicated that the TD group ($M=89.12\%$, $SD=5.78$) was more accurate than was the ASD control group ($M=76.86\%$, $SD=13.94$) ($p<.01$), but no significant differences were found between the TD group and the ASD study group ($M=79.88\%$, $SD=12.37$) ($p=.06$) and between the ASD study group and the ASD control group ($p=.75$). Table 4 presents accuracy data in all conditions.

The two-way interaction of time \times target word was also significant, $F(1, 48)=11.18$, $p=.00$, $\eta^2=.19$. A Bonferroni post-hoc analysis indicated that responses to ironic target words were significantly more accurate after the intervention than before the intervention ($p=.00$). No significant difference in responses to the literal target words before and after the intervention was found ($p=.33$). The two-way interaction of time \times group was significant, $F(2, 48)=3.23$, $p=.05$, $\eta^2=.12$. A Bonferroni post-hoc analysis revealed significantly more accurate responses after the intervention than before the intervention in the ASD study group ($p=.00$) as well as in the TD control group ($p=.03$), but not in the ASD control group ($p=.72$). The two-way interaction of visual field \times target word was significant, $F(1, 48)=6.34$, $p=.01$, $\eta^2=.12$. A Bonferroni post-hoc analysis indicated that responses to ironic target words were significantly more accurate when presented to the LVF/RH than when presented to the RVF/LH ($p=.00$). No significant difference in accuracy on literal target words was found between the LVF/RH and the RVF/LF ($p=.72$). The two-way interactions of time \times visual field, $F(1, 48)=2.49$, $p=.12$, $\eta^2=.05$, visual field \times group, $F(2, 48)=.18$, $p=.84$, $\eta^2=.01$, and target word \times group, $F(2, 48)=1.84$, $p=.17$, $\eta^2=.07$, were not significant.

The three-way interaction of time \times visual field \times group was significant, $F(2, 48)=3.65$, $p=.03$, $\eta^2=.13$. A Bonferroni post-hoc analysis indicated that in the ASD study group no significant difference between the two visual fields was observed either before ($p=.06$) or after the intervention ($p=.87$). In the ASD control group no significant difference between the two visual fields was found before the passive intervention ($p=.69$), but after the passive intervention the LVF/RH was significantly more accurate than was the RVF/LH ($p=.00$). TD participants responded more accurately to stimuli presented to the LVF/RH than to stimuli presented to the RVF/LH before the passive intervention ($p=.04$). No significant difference between the two visual fields was found after the passive intervention ($p=.35$). The three-way interactions of time \times visual field \times target word, $F(1, 48)=.33$, $p=.57$, $\eta^2=.01$, time \times target word \times group, $F(2, 48)=2.08$, $p=.14$, $\eta^2=.08$, as well as visual field \times target word \times group, $F(2, 48)=1.88$, $p=.16$, $\eta^2=.07$, were not significant.

Finally, the four-way interaction of time \times visual field \times target word \times group was not significant, $F(2, 48)=.01$, $p=.98$, $\eta^2=.00$.

Thus, there was no difference in accuracy in the ASD study group between the two visual fields either before or after the intervention. Surprisingly in the ASD control group no significant

difference between the two visual fields was found before the passive intervention but after the passive intervention the LVF/RH was significantly more accurate than was the RVF/LH. TD participants demonstrated more accurate responses to stimuli presented to the LVF/RH than to stimuli presented to the RVF/LH before the passive intervention, but no differences between the two visual fields were observed after the passive intervention.

4. Discussion

Two main results arise from our findings. First, a brief intervention can improve comprehension of irony in adults with ASD. Specifically, adults with ASD who participated in the intervention, which involved identifying irony in video clips, stories and comic strips and creating verbal irony, showed significant improvement in irony comprehension relative to adults with ASD who did not participate in the intervention (i.e. ASD control), as reflected in their performance on the irony questionnaire. Second, the intervention induced hemispheric changes in the ASD study group; whereas no difference in RT between the ironic and the literal stimuli was observed within each hemisphere prior to the intervention, following the intervention, the ASD study group demonstrated faster responses for ironic targets relative to literal target words when stimuli were presented to the LVF/RH.

Performance on the irony questionnaire showed that adults with ASD were less accurate in comprehending ironic than literal passages. Prior to the intervention, scores on literal passages were close to ceiling in both ASD groups, suggesting that the main difficulty lies in the comprehension of irony itself and not in comprehension in general. A comparison of questionnaire results before and after the intervention demonstrated that the comprehension of irony improved only within those individuals who participated in the intervention (i.e., the ASD study group) but not within adults with ASD who were not encouraged to analyze irony or to detect ironic cues but rather participated in a passive intervention (i.e., the ASD control group). It is important to note that testing involved different passages from those that were used during the intervention, implying that the improvement reflects generalization. These findings suggest that the intervention improved comprehension of irony, whereas mere exposure to irony within the ASD control group led to no change in performance.

Performance in the hemispheric experiment supported the results of the irony questionnaire, demonstrating changes in the ASD study group alone, which was the only one involved in the intervention. On the first administration, there was no difference in speed of response to the two types of target words in both ASD groups. However, following the intervention, responses to ironic target words presented to the LVF/RH were faster than responses to literal target words in the ASD study group but not in the ASD control group (who were only exposed to humorous texts with no active intervention). Thus, the ASD control group performed

similarly on both administrations. Moreover, after the intervention, the pattern of responses in the ASD study group resembled the pattern of responses in the TD group prior to the intervention. Other studies have also shown evidence of neural changes due to intervention in the ASD population, although these previous interventions involved social cues (Van Hecke et al., 2015) or face processing (Faja et al., 2012) and were examined with EEG and ERP, respectively. Thus, the current study adds unique evidence regarding changes in hemispheric processing in adults with ASD following intervention.

The fact that responses to ironic and literal targets were initially similar within the ASD study group and were lateralized following the intervention fits in well with the leading theoretical accounts of figurative language processing (Beeman, 1998; Giora, 2002, 2003). Having focused on the comprehension of novel non-salient ironic stimuli within the intervention, participants with ASD began to activate their RH on encounter of these stimuli as was reported for TD participants (Eviatar and Just, 2006; Shibata et al., 2010). Importantly, unlike the change in brain lateralization, demonstrated in the ASD study group for processing of irony, no change occurred in this group for literal targets. This finding further suggests that the change was not simply due to test–retest exposure to experimental stimuli but rather that it resulted from the intervention.

One surprising finding that emerged from the three-way interaction of accuracy data on the experimental task was that, on the second administration of the task, participants in the ASD control group responded more accurately when stimuli were presented to the LVF/RH than when they were presented to the RVF/LH. A closer inspection of the data reveals that the accuracy rate of this group on ironic stimuli presented to the LVF/RH was 70% before the passive intervention and 72% after the passive intervention, and the accuracy rate on literal stimuli was 85% before the passive intervention and 87% after the passive intervention. Thus, although changes were significant, they were rather minor. These minor changes are contrasted with more major accuracy differences in the ASD study group (68% vs. 82% in the LVF/RH, and 62% vs. 82% in the RVF/LH). Thus, the minor differences in accuracy within the ASD control group are most likely the result of a test–retest effect and do not reflect a significant shift in hemispheric processing.

Importantly, despite improvement on both the questionnaire and the experimental task, the ASD study group was more accurate on the questionnaire. These differences could reflect the fact that the questionnaire was completed under no time constraints, so that target presentation was not as brief as it was in the experimental task. Regardless of these differences, participants with ASD demonstrated the ability to comprehend irony. We acknowledge that comprehension of irony in everyday situations places greater demands than were placed in both of the tasks used in the current study but the current findings are nevertheless encouraging.

Changes in the pattern of hemispheric processing were also observed in the TD control group. On the first exposure, TD individuals showed a LH advantage in processing literal stimuli (as compared to ironic stimuli) and a RH advantage in processing ironic stimuli (as compared to literal stimuli), but these differences disappeared on the second exposure. This change might be attributed to the contextual changes induced by the intervention. Gibbs et al. (2014) argue that irony processing changes with context. Once a person adopts an ironic viewpoint, this viewpoint facilitates irony comprehension in other stimuli as well. Thus, the fact that TD participants were exposed to irony both during the first experimental task and during the control passive intervention made irony more salient. As a result, the priority assigned to literal interpretation within the RVF/LH as well as the priority assigned to

irony within the LVF/RH declined, and no hemispheric advantage was seen. Processing of the supposedly non-salient ironic stimuli became similar to processing of salient literal stimuli. These findings are consistent with Mashal and Faust (2009) findings showing a change of hemispheric processing patterns among TD adults when processing novel metaphors at second exposure. Note that in that study, only participants who were asked to think about the meaning of the expressions between the two exposures improved in accuracy to novel metaphoric expressions. It is thus possible that the activation of irony during the control passive intervention in the current study had a similar effect on TD adults.

There are several limitations to this study that should be noted. First, the fact that we used the same questionnaire and the same experiment before and after the intervention makes it difficult to rule out a test–retest effect on performance. Nevertheless, all groups were retested with the same material and changes were different in each group. Thus, a test–retest effect cannot account for the entire pattern of results reported here. Second, performance on the literal stimuli was at ceiling on the questionnaire, and there were only five literal items. However, these factors have little impact on our conclusions regarding the processing of the ironic interpretations. Finally, it is important to acknowledge that the study lacked the use of more robust diagnosis measures for the ASD population such as Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994) and/or Autism Diagnostic Observation Schedule (ADOS-G; Lord et al., 2000).

Future studies should use a larger pool of literal stimuli to determine whether changes in performance occur for these stimuli as well. In addition, with regard to the graded salience hypothesis (Giora, 1997, 2003) our findings may raise a question as to whether the participation in the intervention assisted the ASD study group to better cope with novel non-salient stimuli rather than with irony per se. It is important to pursue this issue of irony comprehension and brain lateralization to novel irony stimuli as compared to salient irony stimuli in ASD as has been done in previous studies using metaphors (Giora et al., 2012).

5. Conclusions

Despite known difficulties in understanding figurative language in general and irony in particular, an intervention that was designed to improve comprehension of irony led to changes in performance among adults with ASD. Thus, individuals who participated in the intervention performed more accurately on an irony questionnaire following the intervention. No such change was seen in an equivalent group of individuals with ASD who did not participate in the intervention but rather participated in a passive intervention. Furthermore, improvement was also seen in hemispheric processing of irony within the study group alone, with better comprehension associated with increased right hemispheric lateralization. After the intervention, performance of participants in the ASD study group resembled performance of TD adults at first exposure to the stimuli. The current study thus suggests that an intervention that focuses on irony can improve comprehension by adults with ASD.

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Table A1

Intervention outline.

Description of content	Session
Participants were given an overview of the program and were introduced to figurative language in general and to irony in particular. Ironic elements were presented, and the purpose of using irony was explained. Participants practiced identification of ironic cues through video clips and written stories.	Session 1: Introduction to verbal irony
Practice followed three steps: 1. Analysis of expression and its context.	Session 2: Analysis and interpretation of ironic expressions
2. Identification of cues to irony. 3. Discussion of speaker intention. Short stories with an open ending were presented and participants were asked to generate either a literal ending or an ironic ending to each story.	
The three step analysis was practiced as before. Then comic strips with open endings were introduced for analysis and discussion.	Session 3: Continued practice
The three step analysis was practiced as before. Following comic strips with open endings were analyzed and discussed. Participants were then asked to describe daily situations in which they encountered irony.	Session 4: Continued practice
The three step analysis was practiced as before, following comic strips with open endings were analyzed and discussed, and participants were then asked to describe daily situations in which they encountered irony. A summary of knowledge presented about verbal irony was provided. Examples of and figurative language in the press were discussed.	Session 5: Continued practice and summary

Appendix A

see Table A1.

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