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Article

# The Relationship between Semantic Joke and Idiom Comprehension in Adolescents with Autism Spectrum Disorder

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**Abstract:** Semantic jokes involve resolving an incongruity emerging from wordplay or from violation of world knowledge. Research has shown individuals with autism spectrum disorder (ASD) demonstrate lower performance on humor tasks involving social situations, but less is known about their semantic joke comprehension. This study examined semantic joke comprehension among adolescents with ASD, and its possible relationship to vocabulary size, theory of mind (ToM), and idiom comprehension. Thirty-two adolescents with ASD and 32 typically developed (TD) peers participated. Semantic joke comprehension was assessed via multiple-choice questionnaire and time-limited computer program. Vocabulary, ToM abilities, and idiom comprehension were also tested. Results revealed that adolescents with ASD were as fast in processing semantic jokes as their age- and vocabulary-matched TD peers but less accurate. Age and idiom comprehension contributed significantly to semantic joke comprehension among both groups. As semantic joke comprehension is based on incongruity resolution, the greater difficulties in comprehension among the adolescents with ASD may be due to deficits in simultaneously retaining two alternative interpretations and selecting the relevant one. Like the TD group, semantic joke comprehension among the ASD group appeared more developed with age. Future neuroimaging studies should test semantic brain region involvement in semantic joke comprehension in ASD.

**Keywords:** autism; humor; semantic joke; idiom; theory of mind

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## 1. Introduction

Humor comprehension is a mental process that emerges from resolving incongruity [1-3]. One type of incongruity occurs in a semantic joke when a “punchline” is inconsistent with its contextual setup, leading to a mismatch with one’s previous expectation [4]. Understanding semantic jokes necessitates resolving incongruity that emerges from violation of world knowledge. For example, “Where’s the place with the cheapest rent?...The prison.” (adapted from [4]). Feelings of amusement and pleasure are elicited when a new piece of information causes a shift in understanding from a primary obvious script to a secondary or opposing script [5]. Another type of semantic joke relies on wordplay or puns, often exploiting multiple meanings of words or phrases, resulting in a surprising new meaning of the words used (e.g., *Two cannibals are eating a clown. One says to the other, “Does this taste funny to you?”*; derived from [6]).

Two leading theories are often used to explain the processes involved in humor comprehension: the incongruity-resolution theory [7] and the comprehension-elaboration theory [8]. In the former, the cognitive processing of humor has been conceptualized as a two-step model: an incongruity-detection stage followed by an incongruity-resolution stage. This theory posits that to resolve incongruity, it must be removed. In the comprehension-elaboration theory, humor comprehension involves encoding a stimulus event based on its features using a schema already stored in memory,

as well as creating inferences based on the information relevant to understanding the event. Elaboration, on the other hand, involves forming a second schema by making conscious inferences about features not explicitly mentioned during the previous comprehension stage. This theory posits that activation of the second schema allows the simultaneous existence of two incompatible interpretations. Both theories attempt to explain the tension elicited from an interpretation that does not match the straightforward meaning supplied by the set-up.

Delving more deeply, while neural activity can already activate upon encountering even the first few words of a joke, this activation changes as a joke is ultimately comprehended. The path of this neuronal activity is complex and enlists several networks: frontal and temporal brain regions to process the joke's semantic information, and the subcortical and mesolimbic system to enjoy the reward that the joke's resolution brings [9]. For example, an fMRI study found that a joke's punchline activated language and semantic neural networks associated with incongruity detection and resolution [10]. These networks included the inferior frontal gyrus (IFG), middle temporal gyrus (MTG), superior temporal gyrus (STG), superior frontal gyrus (SFG), and inferior parietal lobule (IPL). The experience of amusement resulted in greater activation in reward regions, including the amygdala, nucleus accumbens, midbrain (VTA), and hypothalamus; furthermore, greater subjective funniness ratings were associated with increased activation in dopaminergic reward regions [10]. Thus, when a punchline is fully understood the brain releases neurotransmitters such as dopamine, shifting the focus of brain's response to its pleasure-and-reward center, evoking the hedonic aspects of humor [9]. A recent meta-analysis [11] confirmed the involvement of the IFG and the middle and superior temporal gyri in humor comprehension regardless of stimulus type (visual or verbal, although activation was also observed in right homologues regions as well). These brain regions are involved in language and semantic integration processes required for most humor tasks.

As for the response elicited by humorous stimuli, neural activation has been primarily observed in the medial prefrontal cortex, bilateral amygdala, ventral anterior cingulate cortex, and thalamus, corresponding to the emotional (amusement) response provoked by the unexpected "twist" in meaning and resolution of incongruity embedded within the humorous stimulus. Moreover, utilizing humorous stimuli based on theory of mind (ToM)—the ability to think about and act on information about one's own and others mental states [12] such as jokes or cartoons in which incongruity arises from processing the players' mental states [13-16]—studies have found activation mainly located in the medial prefrontal cortex and the temporo-parietal junction. Although findings from neuroimaging studies of humor processing can differ depending on the research task, stimulus type, and modality utilized, many researchers approach humor as a multifaceted function involving both a cognitive and an affective processing stage (e.g., [13,17-19]).

The understanding of humor develops over the life course, playing an important role in social interactions and in the formation of strong interpersonal connections [20,21]. The development of humor processing in most children with typical development (TD) increases with age. At ages 2-3 years, a child with TD already creates situations of incongruity in their own inner world in a symbolic game with objects [22] even before they have developed the ability to understand *the other's* mind. Around age 8, children with typical development can understand when a speaker says one thing but means another. At ages 10-14, TD children can understand verbal jokes that include incongruity and complex lexical structures [22,23]. Age, indeed, plays an important role in understanding figurative language, as the development of advanced language skills and competencies facilitates the processing of complex expressions that require distinguishing between literal and figurative meaning (what we say vs. what we mean) [24]. Humor understanding thus develops over years and peaks in adolescence [22,23].

Accumulating evidence suggests that children with autism spectrum disorder (ASD) experience difficulties understanding non-literal language (of which humor is one subtype) including irony [25-27], metaphors [28-30], and idioms [29,31,32]. Evidence also suggests they tend towards literal interpretations of idioms instead of their lexicalized idiomatic meaning [29,33] and show difficulty understanding and enjoying jokes, especially those that require considering people's (false) mental states [34]. Asperger [35] was one of the first to describe the tendency among autistic individuals to

fail to comprehend jokes or appreciate humor in general. Subsequently, Wu et al. [36] showed that adolescents with ASD had specific challenges resolving jokes involving incongruity, compared to controls, and preferred nonsense jokes using homophones that create double meaning over jokes involving logical reasoning.

Several theories attempt to explain the source of the observed difficulties among those with ASD in understanding humor. Several scholars argue that theory of mind, a known core deficit in autism [37,38], is necessary for humor comprehension [39]. A recent study demonstrated that ToM skills (assessed by the Strange Stories task) predicted comprehension of mental jokes, but not phonological-based jokes, in older neurotypical adults [40]. Further, a study using cartoons with and without ToM content found that neurotypical individuals with higher autistic traits failed to comprehend humorous cartoons only when ToM was necessary for understanding [41]. Among those with ASD, evidence has suggested that ToM skills are linked to comprehending jokes requiring social situational understanding [12,34,42].

Non-literal language comprehension, in which one must fill the gap between the literal meaning and the intended figurative meaning, has also been linked to mentalizing ability (e.g., [43,44]). Specifically, first order ToM ability has been associated with metaphor comprehension while second order ToM skills have been linked to irony comprehension [45]. Consistent with this finding, idiom comprehension has been found associated with ToM ability in children with ASD but not in children with TD [46]. One form of assessing mentalizing ability is using the Hinting test [26,47,48] that assess the ability to understand the intentions of others. Indeed, irony understanding has been linked to Hinting test understanding in adolescents with ASD [26]. Although the current study focuses on semantic jokes that do not involve social situational understanding, it will explore whether semantic jokes (as manifestations of non-literal language) may be linked to mentalizing abilities as was found in irony comprehension [26].

Alternative sources for the humor comprehension differences observed in ASD have been proposed. One interpretation has suggested they stem from difficulties in core language skills (e.g., vocabulary, syntax, semantics) critical to comprehension of figurative language [49]. Another interpretation is the weak central coherence (WCC) theory [50-52] that posits a processing style of focusing on details rather than the “whole picture.” Instead of perceiving the humor’s message level, individuals with ASD tend to focus on joke’s setup details that are irrelevant to the main message [12,53,54]. Others suggest the difficulties are sourced in executive functions characteristic of children with ASD [55] such as challenges in working memory, shifting abilities, mental flexibility, and selective attention, all of which are involved in humor comprehension [12]. Indeed, a recent study [32] showed that ToM ability (as assessed by the Hinting test) and mental flexibility predicted comprehension of ironic comic strips beyond group affiliation (TD or ASD) among adolescents aged 10-16 years. Thus, various factors that typically characterize the ASD phenotype may affect joke comprehension [56,57].

To further explore how individuals with ASD may process semantic jokes differently, and to assess to what extent joke comprehension processing is difficult, accuracy and reaction time can be a useful measure of the underlying cognitive processing. However, few studies have measured reaction time to humorous stimuli among those with ASD. One study, conducted via computer, asked participants to decide whether cartoons with or without ToM content were funny [41]. While the study finding did not reach significance, participants with high autistic traits showed longer reaction times for all cartoons, regardless of ToM content, and exhibited poorer humor comprehension on cartoons relying on ToM. Thiébaut et al. [58] also found a trend toward slower reaction time for participants with ASD, compared to neurotypical participants, when presented with a humor comprehension task (faux pas vs. non-faux pas cartoons). While a significant group by cartoon type interaction was not found, participants with ASD reacted more slowly to both types of cartoons. Although suggesting a tendency toward slower reaction times and reduced accuracy among those with ASD or high autistic traits, cartoons were the only medium of humor stimuli tested, leaving a knowledge gap as to whether verbal semantic jokes might be processed more slowly or less accurately.

Moreover, the existing literature on this topic is sparse and inconclusive and has primarily focused on either adults [41,58] or children [59,60]. In the current study, semantic joke comprehension is measured utilizing two different tasks: a multiple-choice questionnaire and a computerized time-limited task. The multiple-choice questionnaire is a well-established measure of semantic joke comprehension by tasking participants to choose a punchline to complete given lines of text by selecting one from among a few types of endings: funny, straightforward (not funny), or nonsensical [61,62]. The funny endings were based on wordplay and violation of expectations (violation of world knowledge). The second semantic joke comprehension task was a time-limited computerized test that examined three types of utterances: semantic jokes (based on wordplay), literal sentences, and nonsense sentences [63]. Idiom comprehension was tested utilizing a multiple-choice questionnaire. The relationship between comprehension of idioms and semantic jokes was thus examined among adolescents with ASD for the first time.

The aims of the present study were twofold: (1) to examine semantic joke understanding among adolescents with ASD compared to age- and vocabulary-matched TD controls; and (2) to examine the contribution of various abilities (vocabulary, ToM, and idiom comprehension) to semantic joke comprehension among adolescents with ASD and TD. We hypothesized that the adolescent TD group would score higher than the ASD group on the semantic joke comprehension questionnaire [54] and respond more accurately to semantic jokes on the computerized task, with no difference in reaction times between groups [41,58]. We also hypothesized no group differences in the reaction times to nonsense sentences [36,64]. Finally, we hypothesized idiom understanding and age would contribute to humor comprehension in both groups [12,24].

## 2. Materials and Methods

### 2.1. Participants

G\*power software was used to determine a priori the sample size. For the primary analyses of a mixed-design ANOVA with repeated measures (3X2) and an effect size of 0.30 (small-medium),  $\alpha$  error = 0.05, and power = 0.80, the total sample size required was 62 participants. To increase power and sensitivity, the present study included 64 participants, of whom 42 were male, 22 were females, and whose ages were between 11 and 16 years ( $M = 13.64$ ,  $SD = 1.09$ ). The adolescents, all native Hebrew speakers, were divided into two groups: those with a diagnosis of ASD and those with TD. The ASD group was comprised of 32 adolescents (22 males, 10 females) aged 12-15 years ( $M = 13.69$ ,  $SD = 0.96$ ). The TD group was comprised of 32 adolescents (20 males, 12 females) aged 11-16 years ( $M = 13.59$ ,  $SD = 1.21$ ). No statistical differences were found between the two groups in gender distribution or in age [ $\chi^2 (1) = .28$ ,  $p = .599$ ,  $t(62) = .34$ ,  $p = .734$ ,  $d = .09$ , respectively] (see Table 1). ASD diagnosis was previously determined by a psychiatrist according to the Diagnostic and Statistical Manual of Mental Disorders DSM-5 [65] criteria.

Recruitment of participants was conducted in accordance with institutional research guidelines, and protocol approval had been received by the Israeli Ministry of Education. Letters were sent to parents about the study, requesting consent for their child's participation; children whose parents provided signed informed consent were asked to participate. Adolescents with ASD were recruited from integrated classes within elementary and junior high schools while those with TD were mostly recruited from junior high schools. Some participants were recruited by friends.

### 2.2 Tests

Various tests were used to assess participants' vocabulary, theory of mind abilities, idiom comprehension, and semantic joke comprehension (see Table 1).

#### 2.2.1 Vocabulary

Vocabulary knowledge was examined using the vocabulary subtest of the Wechsler Intelligence Scale for Children—Hebrew (WISC-IV<sup>HEB</sup>; [66]). In this task, the participants were asked to provide definitions for the 28 words they heard. Scores ranged from 0-70.

### 2.2.2 Theory of Mind (ToM)

ToM ability was assessed using the Hinting test. This test measures comprehension of others' intentions [48]. The task was originally designed by Corcoran et al. [47] and was professionally translated into Hebrew for a previous study [26]. Participants were asked to provide ten short stories involving interactions between two speakers. Each story ended with one speaker "dropping a hint." After listening to the story, participants were asked about the speaker's intentions (i.e., what the speaker really meant). For example: 'Rebecca's birthday is approaching, so she said to her dad, "I love animals, especially dogs." Question: What does Rebecca really mean when she says this?' A correct answer describes the speaker's tacit intention. Each correct answer received two points. If participants failed to answer they were given additional information. Example of added information: 'Rebecca goes on to ask, "Is the pet shop open on my birthday?" Question: What does Rebecca want her dad to do?' A correct response after additional information was provided received one point. If participants again failed to infer the intended meaning, a score of zero was received for the item. Total scores ranged 0-20.

### 2.2.3 Idiom Comprehension

This multiple-choice questionnaire examined comprehension of idioms [29]. Participants were presented with 20 idioms in Hebrew with plausible literal interpretations (e.g., he got cold feet). Each idiom was followed by four interpretations: a correct idiomatic interpretation, a literal interpretation of the idiomatic expression, a literal distracter related to or repeating the verb of the idiom, and an unrelated interpretation. Participants were instructed to read each idiom carefully and choose the correct interpretation. Each correct idiomatic interpretation received one point, and total scores ranged 0-20.

**Table 1.** Participant gender, age, and performance on assessments of abilities, by group

Background Characteristics	ASD	M(SD)	TD	M(SD)	t	p	Cohen's d
Gender (Males/Females) <sup>1</sup>	22 / 10		20 / 12		.28	.599	---
Age	13.69 (0.96)		13.59 (1.21)		.34	.734	0.09
Vocabulary	39.41 (5.70)		40.13 (7.68)		-.42	.672	0.11
Idiom Comprehension <sup>1</sup>	14.03 (4.28)		18.69 (1.82)		5.66***	.001	1.42
ToM <sup>2</sup>	14.22 (3.02)		18.13 (1.72)		6.35***	.001	1.59

<sup>1</sup>Chi square analysis was conducted; <sup>1</sup>df = 41.855; <sup>2</sup>df = 49.124; \*\*\* p< .001

As seen in Table 1, groups did not significantly differ by gender, age, or vocabulary but the TD group scored higher than the ASD group in idiom comprehension and ToM.

### 2.2.4 Semantic Jokes

#### 2.2.4.1 Semantic joke comprehension: multiple-choice questionnaire

This questionnaire examined the comprehension of semantic jokes and was based on the humor subtest of the Assessment of Pragmatic Abilities and Cognitive Substrates (APACS). The APACS was originally designed by Arcara and Bambini [61] to examine pragmatic language. This test was subsequently translated into Hebrew, modified to overcome cultural differences, and validated for those age 16 and over (Cronbach's alpha =.78) [67]. Participants were provided with short vignettes to read and asked to choose a funny ending from among three options: a straightforward ending, an unrelated ending, and a humorous ending. For example: Mrs. Rossi visits a friend of hers. Upon seeing a beautiful piece of antique furniture, she exclaimed: "What a splendid piece! When does it date back to?" Her friend replied... [1. "To when we used to have money" (funny ending = correct); 2. "To the eighteenth century" (straightforward ending = incorrect); 3. "Woodworm is such a problem" (unrelated ending = incorrect)]. The funny endings were based on two types of semantic jokes: those based on wordplay or those based on violation of world knowledge.

The original APACS humor subtest includes seven vignettes, but after translation into Hebrew two were removed due to the humorous punchline being “lost in translation.” To increase the number of the items in the questionnaire, 12 additional vignettes were composed in Hebrew by the study authors, and a pre-test was conducted with a separate group of participants to evaluate the humorous endings. Twenty TD individuals (10 females and 10 males;  $M_{age} = 23.75$ ,  $SD = 4.99$ ) participated in the pretest. Participants were asked to rate the degree to which they found the ending of each vignette amusing on a scale of 1 (not amusing at all) to 5 (very amusing). Five items whose mean level of amusement was higher than three ( $M = 3.39$ ,  $SD = 0.43$ ; range = 3.2-4) were added to the questionnaire. Thus, the revised humor questionnaire contained 10 vignettes, and total scores ranged 0-10. Participant scores on the five original vignettes of Arcara and Bambini (2016)[61] and on the five vignettes created for the current study were highly correlated,  $r(62) = .75$ ,  $p < .001$ . Internal consistency (Cronbach’s alpha) for all 10 vignettes was high,  $\alpha = .78$ .

#### 2.2.4.2 Semantic joke comprehension: Computerized experiment

This task examined reaction times and accuracy in processing semantic jokes [63]. The stimulus pool consisted of 90 Hebrew sentences of three types: 30 semantic jokes, 30 literal sentences, and 30 nonsense sentences. Semantic jokes (e.g., *The beggar asked the ice cream seller for some money. His response was quite cold.*) were constructed such that the last word was polysemic, i.e., having several meanings (e.g., *cold*), and evoked two associations: 1. the contextually relevant meaning derived from the setup content (unfriendly) and 2. the contextually irrelevant meaning (low temperature). Thus, while reading the humorous setup, the reader is biased toward choosing the contextually relevant ‘unfriendly’ meaning while simultaneously ignoring the irrelevant ‘low temperature’ meaning. Because both associations are activated, the reader feels enjoyment in the joke’s resolution. In contrast, literal sentences had only one meaning (e.g., *Ron bought groceries at the supermarket. He bought dairy products and fruits.*) and nonsense sentences ended with an unrelated final word (e.g., *Ashley came back from a bike ride. She drank chocolate and ate a wave.*) (see Table 2 for more examples).

**Table 2.** Examples of stimuli used in the computerized task

Semantic Joke	Literal Sentence	Nonsense Sentence
I told Isaac the tailor a good joke. He was in stitches.	John was excited during the flight. He especially liked to fly above the clouds.	Sarah had a big test yesterday. She studied and during the test she had a lake.
The children waited a very long time at the airport before deciding to go home. Time did not fly.	The baby was very tired. His mother decided that now he should be put to sleep in bed.	Tammy went to the mall. She went into a jewelry store and bought a fly.
Bad traffic caused Taylor to stay home with her baby. It was crawling.	David went outside after the rain. He looked to the sky and saw a rainbow.	Romi decided to go jogging this morning. She ran down the street to the mustache.

Note: Almost all of the original Hebrew semantic jokes did not translate meaningfully into English (i.e., retaining their humor), so the examples provided in English are for illustrative purposes only.

Several pre-tests were performed to generate the stimuli. The first pretest aimed at examining whether the semantic jokes’ final words evoked the two intended associations: the contextually relevant meaning and the contextually irrelevant meaning linked to the sentence’s noun (either the subject or direct object). Ten participants (age range: 20–35 years;  $M = 26.26$ ,  $SD = 4.35$ ) participated in the first pretest and were presented with pairs of words: the sentences’ final words coupled with the relevant meaning (e.g., *cold=unfriendly*) and irrelevant meaning (e.g., *cold=low temperature*). Participants were told: “Here are word pairs that may be: semantically related (clothes dress), a word and an adjective (safe travel), a familiar phrase (pay attention), or semantically unrelated (decision environment). Rate the strength of the association between each word pair on a scale from “1 = not related at all” to “7 = very related.” The results indicated that the strength of the association of

contextually relevant meaning word pairs ( $M = 5.72$ ,  $SD = 0.76$ ) did not differ from the contextually irrelevant meaning word pairs ( $M = 6.01$ ,  $SD = 0.69$ ),  $t(29) = 1.81$ ,  $p > .05$ .

The second pre-test was aimed at examining to what extent the final word of each joke was surprising and enjoyable. Thirty participants (10 males) aged 18–34 years ( $M = 27.4$ ,  $SD = 5.42$ ) participated in this pre-test. These participants did not take part in the first pre-test or in the live experiment and were asked to rate how surprising the last word in each sentence was on a scale from “1 = not at all surprising” to “7 = very surprising”. The participants were also asked to indicate to what extent the sentences were enjoyable for them on a scale from “1 = not at all enjoyable” to “7 = very enjoyable”. All items rated above 4 on each scale (surprising:  $M = 5.08$ ,  $SD = 0.47$ , enjoyable:  $M = 5.01$ ,  $SD = 0.59$ ) confirming their amusement from the semantic jokes.

In addition, analyses were performed to counterbalance conditions according to the final word’s syntactic category, frequency, and length. There were five types of syntactic category: adjectives, nouns, verbs, words that are both nouns and adjectives, and words that are both verbs and adjectives. Word frequency was based on internet norms data [68] (semantic jokes:  $M = 6235$ ,  $SD = 14607$ , literal:  $M = 6235$ ,  $SD = 14607$ , nonsense:  $M = 6367$ ,  $SD = 16139$ ), and the length of the final word was also counterbalanced between conditions (semantic jokes:  $M = 4.50$ ,  $SD = 1.54$ , literal:  $M = 4.47$ ,  $SD = 1.25$ , nonsense:  $M = 4.50$ ,  $SD = 1.38$ ),  $F(2, 27) = 0.006$ ,  $p = .99$ .

#### 2.2.4.3 Procedure for the computerized semantic joke experiment

Participants sat in front of a computer screen at a comfortable viewing distance. Stimuli were displayed via SuperLab version 5.0 software on a laptop (Cedrus Corp., San Pedro, CA). First, a fixation point appeared at the center of the screen for 2,000 ms, and once the point disappeared, a sentence was presented in the center of the screen. Participants were asked to press the button when they finished reading the sentence. Next, a fixation point was presented for 250ms, after which the target stimulus (the sentence’s final word) appeared in the center of the screen and remained there for 1000ms. Participants were instructed to decide whether the final word made a *logical* ending to the sentence, indicating “yes” (by pressing the N keyboard key with their right finger) or “no” (by pressing the B keyboard key with their right finger). They were asked to make the semantic decision as accurately and as quickly as possible. The semantic jokes, literal sentences, and nonsense sentences were presented in a random order. Each session began with a practice session of nine trials not included in the live experimental session.

#### 2.2.4.4 General experimental procedure

Parents had provided signed informed consent for their child’s participation in the study, and after receiving an explanation of the study, adolescents agreeing to participate were enrolled. After completing tasks assessing vocabulary, idiom comprehension, and ToM, they performed the computerized task. Following a 10-minute break, participants were then asked to complete the multi-choice joke questionnaire.

### 3. Results

We conducted Mauchly’s test to examine the sphericity assumption. For those cases in which the assumption of sphericity was rejected, we report the adjusted degree of freedom ( $df$ ) in decimal number format.

#### 3.1. Semantic Joke Comprehension Questionnaire

To examine possible differences between ASD and TD participants in semantic joke comprehension questionnaire scores, we conducted *t*-test analysis for two independent samples. A significant difference between the two study groups was found,  $t(62) = 4.86$ ,  $p < .001$ , indicating lower accuracy among the ASD ( $M = 5.94$ ,  $SD = 2.51$ ), compared to the TD, group ( $M = 8.63$ ,  $SD = 1.86$ ).

### 3.2. Computerized Semantic Joke Experiment

Performance on the computerized semantic joke experiment was analyzed by a two-way (2x3) mixed ANOVA. One analysis was performed on reaction times and the other on accuracy (percent correct responses). Independent variables were Group as the between-subjects factor (ASD, TD) and Stimuli Type as the within-subjects factor (semantic jokes, literal sentence, nonsense sentence) (see Table 3).

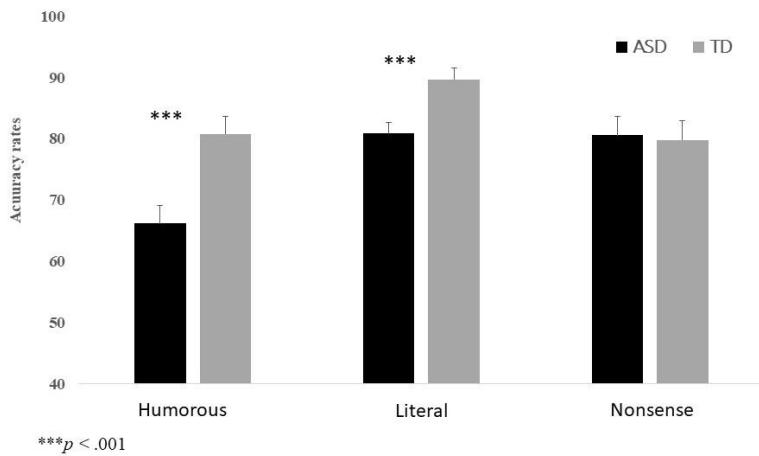
**Table 3.** Mean (SD) reaction times and accuracy rates on the computerized semantic joke experiment, by group and stimuli type

Stimulus Type	ASD (n=32)		TD (n=32)		F values		
	M	SD	M	SD	Group	Stimulus Type	Interaction
<b>Reaction Times</b>							
Semantic Jokes	1424.39	373.10	1286.22	363.62	2.32	49.21***	1.14
Literal	1307.96	341.65	1152.46	328.14			
Nonsense	1438.31	362.11	1332.11	377.29			
<b>Accuracy Rates</b>							
Semantic Jokes	66.15	18.28	80.73	13.93	11.43***	10.43***	4.44*
Literal	80.83	9.27	89.69	10.82			
Nonsense	80.52	17.19	79.79	17.82			

\*p < .05, \*\*\*p < .001

*Reaction times:* The main effect of Stimulus Type was significant,  $F(1.770,109.749) = 49.21, p < .001$ ,  $\eta_p^2 = .44$ . Pair-wise comparisons indicated faster reaction times for literal sentences compared to the semantic jokes or nonsense sentences ( $p < .001$ ). No significant difference was found in the reaction times for the semantic jokes and nonsense sentences ( $p = .375$ ). No significant main effect of Group or interaction for Group and Stimulus Type were found [ $F(1,62) = 2.32, p = .133, \eta_p^2 = .04$  and  $F(2,124) = 1.14, p = .324, \eta_p^2 = .02$ , respectively].

*Accuracy rate:* The main effect of Group was significant,  $F(1,62) = 11.43, p = .001, \eta_p^2 = .16$ . The results indicated that the accuracy rates in the computerized semantic joke experiment were significantly higher among the TD students compared to the ASD students. The main effect of Stimuli Type was significant,  $F(1.448,89.765) = 4.44, p = .025, \eta_p^2 = .07$ . Pair-wise comparisons indicated that the accuracy rate was significantly higher for literal sentences compared to the semantic jokes ( $p < .001$ ). No significant differences were found in the accuracy rates between nonsense sentences and jokes or literal sentences ( $p = .130$  and  $p = .131$ , respectively). Finally, a significant interaction for Group and Time was found,  $F(2,124) = 4.44, p = .014, \eta_p^2 = .07$ . Bonferroni analyses comparing the two study groups for each stimulus type indicated that while significant differences were found between the two study groups in the accuracy rate for semantic jokes and literal sentences ( $p < .001$ ), no significant difference was found for the nonsense sentence type ( $p = .868$ ). The results thus indicated that the accuracy rates for semantic jokes and literal sentences were significantly higher among the TD students compared to the ASD students (see Figure 1).



**Figure 1.** Percent of accuracy rates in the computerized semantic joke experiment by group and stimulus type (Humorous=semantic jokes)

*Speed-accuracy trade-off:* Pearson correlations were conducted between the accuracy rates and the reaction times for each study group and each condition, separately. The results indicated no significant correlations between the accuracy rates and the reaction times for the computerized semantic joke experiment in both groups [Pearson coefficients between -.31 and .02 and *p*-values between .082 and .898], indicating no speed accuracy trade-off in the computerized semantic joke experiment among both groups.

### 3.3 Regression Analysis

To examine our second hypothesis regarding the contribution of the participants' gender, age, vocabulary, idiom comprehension, and ToM to their score on the semantic joke questionnaire, a hierarchical regression analysis was conducted for each study group. In the first step of the regression model, the students' background characteristics (gender, age) were entered in a step-wise manner. Only variables that contributed significantly to the explained variance (EPV) were entered (see Table 4). Scores on vocabulary, idiom comprehension, and ToM tests were entered next in a step-wise manner.

**Table 4.** Hierarchical regression analyses for the humor comprehension questionnaire scores by participant characteristics for each study group

Independent Variables	B	SE.B	$\beta$	$R^2$	$\Delta R^2$
<b>ASD (n = 32)</b>					
Step 1: Age	.91	.44	.35*	.123*	.123*
Step 2: Age	.63	.38	.24		
Idioms	.32	.08	.54***	.409***	.286***
<b>TD (n = 32)</b>					
Step 1: Age	.55	.26	.36*	.128*	.128*
Step 2: Age	.09	.20	.06		
Idioms	.76	.13	.74***	.585***	.457***

\**p* < .05, \*\*\**p* < .001

As Table 4 demonstrates, the participants' age contributed significantly to the EPV of the semantic joke questionnaire scores for both the ASD and TD groups (12.3% and 12.8%, respectively). In the second step the participants' scores on the idiom comprehension test contributed significantly to the EPV of the semantic joke questionnaire scores for both groups (ASD: 28.6%, TD: 45.7%). The

positive  $\beta$  coefficients indicate that as the participants' ages and idiom test scores increased, the semantic joke comprehension increased, respectively.

It should be noted that the contribution of the idiom comprehension test scores to the EPV of the semantic jokes questionnaire scores was almost twice as much among the TD students compared to the ASD students. In order to examine whether the grouping variable served as a mediating variable between the idiom test scores and the semantic joke questionnaire scores, a moderation analysis using Process software was conducted [69]. The results indicated a significant interaction [ $R^2 = 3.88\%$ ,  $F(1,60) = 5.68$ ,  $p = .020$ ], meaning that the grouping variable served as a mediating variable between the idiom test scores and the semantic joke questionnaire scores.

#### 4. Discussion

The current study investigated semantic joke processing among adolescents with ASD compared to age- and vocabulary-matched TD peers. Our results indicated that adolescents with ASD understood fewer semantic jokes than their TD peers, both via multiple-choice questionnaire and via a timed computerized task. Notwithstanding, participants with ASD were as fast as their TD peers in processing semantic jokes and literal sentences. Age and idiom comprehension contributed significantly to semantic joke understanding scores for both groups, but idiom comprehension contributed twice as much to semantic joke understanding for the TD, compared to the ASD group.

As expected, and consistent with previous studies [12,60,70], participants with ASD demonstrated reduced ability in both semantic joke comprehension tasks compared to their TD peers. Various studies point to difficulties in understanding humor among those with ASD regardless of the type of task utilized, whether involving computers [41], questionnaires [36], or video clips [60]. Further, previous evidence has suggested that individuals with ASD perform less well than controls in understanding jokes that relies on ToM ability and understanding social situations (i.e., mental jokes) [41,58,71]. However, rather than using social scenarios relying on ToM abilities (mental jokes), in the present study, we used semantic jokes either based on wordplay that required suppressing irrelevant associations or based on violation of expectations that required resolution of word knowledge violations. For instance, in the computerized semantic joke task, two different associations were activated by each item's final word: the contextually relevant meaning and the irrelevant association. Participants had to focus on the contextually relevant association, and ignore the irrelevant one, in order to comprehend the joke. Indeed, several studies have indicated that people with ASD tend to have difficulty with verbal tasks that include solving ambiguous sentences [72,73] and that require using context in order to understand the text [74]. A possible explanation for our findings may be linked to the weak central coherence theory. As individuals with ASD tend to focus on small details, the ability to ignore the irrelevant association may pose an obstacle for correct joke interpretation among this population [34,54].

The current study also found no differences in reaction times between groups on the computerized semantic joke task. That said, the ASD group in our study tended to respond to the semantic jokes more slowly in comparison to the TD group (1424ms vs. 1286ms, respectively), despite the data not reaching statistical significance. This finding reflects previous findings that also did not reach statistical significance [41,58] of a tendency toward slower processing times of semantic jokes among those with ASD compared to those with TD. Our study further expanded the existing ASD literature by examining RTs among participants with ASD who read verbal jokes and performed a semantic judgment task, whereas Aykan and Nalçacı's [41] study had participants decide whether a cartoon was funny or not. Thus, it may be that when humor tasks are based on decoding pictorial information that involves social understanding, or are based on incongruity resolution, a trend is seen in which those with ASD need more time than TD controls to process humor. However, further research is needed to determine whether this observation has true statistical significance.

It should also be noted that no trade-off between reaction times and accuracy was observed. It is possible that, as previously pointed out, individuals with ASD can enjoy (appreciate) a joke without necessarily understanding it [36]. Moreover, although high school students with ASD have been found to exhibit less comprehension of all types of jokes than TD controls, they still have a sense of

humor and report enjoyment from reading nonsense jokes. Indeed, unlike the semantic jokes and the literal sentences, ASD participants processed the nonsense sentences as accurately and as fast as the TD group.

We also sought to identify the extent to which background characteristics (gender, age) as well as vocabulary size, ToM ability, and idiom comprehension scores contribute to predicting semantic joke comprehension (as assessed by the semantic joke questionnaire). Our findings indicated that age contributed to semantic joke comprehension in both study groups. It has been previously posited that, among TD individuals, verbal humor understanding develops between 10-14 years of age [22], at which point they can understand verbal jokes that include incongruity and complex lexical structures [22]. The current study participants were similarly aged (11-16 years) and indeed age was found to significantly contribute to semantic joke understanding. To our knowledge, these findings are the first to indicate that age predicts semantic joke understanding among adolescents with ASD. Notwithstanding, more studies are needed to further examine the development of joke comprehension among those with ASD using variety of tasks and age ranges.

Our results also showed that idiom comprehension was a significant predictor of semantic joke comprehension in both groups. This finding is not surprising given that idiom understanding, similar to other components of figurative language, shares the needed ability to compute the nonliteral contextually relevant interpretation of an expression and to suppress the irrelevant literal interpretation [12,32,49]. Notably, in our study, idiom comprehension contributed to predicting semantic joke comprehension questionnaire scores almost twice as much among the adolescents with TD as compared to the ASD participants. Unlike the developmental course of figurative language (i.e., idioms and humor) among individuals with TD [22,75], figurative language development seems to be delayed in ASD [76]. It has been purported that its development among individuals with ASD depends more on their unique cognitive profile, the features of which are thought to include weak central coherence [54], mind blindness [39], and impaired executive functions [57]. The current study findings thus indicate that semantic joke understanding was indeed linked to group such that individuals with TD appeared to have a more developed ability to understand figurative language such as idioms and this ability was in turn linked to their higher ability to understand semantic jokes.

No contribution of ToM ability and vocabulary size to semantic joke understanding was found in the current study. While the ability to understand the intentions of *the other* is extremely important for humor comprehension [39], the current study's humor was based on wordplay and violation of expectations in which the reader had to focus on the relevant interpretation while suppressing the irrelevant association. According to the comprehension-elaboration theory [8], humor comprehension involves activating a schema already stored in memory, followed by an elaboration stage that involves forming a second schema that allows the simultaneous activation of two incompatible interpretations. It is plausible that the participants with ASD were less efficient in forming or maintaining these two schemas concurrently and this may have contributed to the reduced comprehension of semantic jokes found among our ASD cohort [12,34].

There are study limitations that should be mentioned. The abilities we tested besides semantic joke comprehension (vocabulary size, idiom comprehension, ToM) were rather limited and need to be expanded to include a broader range of central coherence abilities and executive functions in order to determine their contribution to successful semantic joke comprehension [52]. Also, given the sparse research on the development of humor comprehension in ASD, future studies should test a broader age range and various types of humor (including mental jokes).

## 5. Conclusions

Our findings showed that adolescents with ASD understood semantic jokes less well than their age- and vocabulary-matched TD peers across two tasks (a multiple-choice semantic joke questionnaire and a computerized semantic joke task). Idiom comprehension contributed significantly to predicting semantic joke comprehension (beyond vocabulary size and ToM ability) in both groups, but more so for the TD group. These findings suggest that one difficulty in semantic joke comprehension among adolescents with ASD may be related to reduced ability to understand

idioms, possibly due to challenges creating or maintaining two alternative interpretations and selecting the relevant one. However, similarly to the TD group, their understanding of semantic jokes becomes more developed with age. Future studies should examine the involvement of language and semantic integration brain areas (IFG and middle and superior temporal gyri) as well as their right homologues brain regions required for semantic joke comprehension tasks, in order to gain deeper insight into the brain bases of humor comprehension in ASD.

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