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Disentangling principle C: A contribution from individuals with brain damage☆

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Abstract

We suggest a disentangling approach according to which the use of referring expressions obeys two types of guidelines. Deviance in repeating referential expressions (R-expressions) can result from two possible sources: one is the violation of the syntactic principle C, ruling out configurations in which c-command holds between the two identical R-expressions; the other is a Go-Lighter (GL) economy principle, applying in discourse and arguably based on shared knowledge and theory of mind (TOM), operative also in environments in which c-command does not hold. To examine this disentangling approach, we tested 36 brain-damaged patients: 20 who had aTOMia, a deficit in TOM, and 16 brain-damaged patients with good TOM, and 29 healthy control participants. Experiment 1 tested the comprehension of principles A and B using a sentence-picture-matching task. Experiment 2 tested principles C and GL using a sentence-choice task. Experiment 3 tested sentence interpretation according to principles C and GL using sentence-picture matching. In line with the disentangling approach, the individuals with poor TOM (and good syntax) failed to rule out and interpret repeating expressions that rely solely on the Go-Lighter principle, but succeeded in judging and interpreting sentences in which the repetition is ruled out by the syntactic principle C.

Keywords: Theory of mind; Right hemisphere damage; Principle C; Repeated name penalty; Syntax; Binding principles; aTOMia; Hebrew

1. Introduction

In the original use, the term *anaphora* referred to the rhetorical figure by which the speaker repeats the same word or expression. What makes it a rhetorical device is that in normal language use, speakers tend not to repeat referential noun phrases, proper names, and definite descriptions (R-expressions). Instead, in the second mention, they tend to use a pronoun or other referentially dependent elements through which the hearer is expected to identify the referent. Linguists worked on constraints on repeating R-expressions and suggested syntactic accounts for this issue, focusing on proper names that repeat within the same sentence in certain structural configurations (Chomsky, 1981; Lasnik, 1989). A preference to avoid repeating expressions has also been studied by a long tradition of psychologists and psycholinguists who refer to a ''repeated name penalty'', where the avoidance of repetition is ascribed to discourse principles (Almor, 1999; Almor and Eimas, 2008; Almor and Nair, 2007; Ariel, 1990, 2001, 2013; Gordon et al., 1993, 1999,

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2004; Gundel et al., 1993; Swaab et al., 2004). In this work we would like to provide evidence that both types of accounts are needed, but that they apply in different structural conditions.

Classical binding theory (Chomsky, 1981) captures the way in which speakers express referential dependencies between different classes of nominal expressions. Within classical binding theory, three principles determine the interpretation of nominal expressions. Two principles, A and B, deal with referentially dependent expressions, anaphors (reflexives and reciprocals) and pronouns respectively, and one principle, principle C, constrains the interpretation of R-expressions. The critical configurations for principles A and B involve local domains, and the structural configuration of c-command is the crucial formal relation referred to by the three principles. C-command is a relation between two nodes, whereby node X *c-commands* node Y when the first node dominating X also dominates Y (and neither dominates the other).

For anaphors, principle A specifies that an anaphor requires a local c-commanding antecedent. For pronouns, principle B requires the lack of a local c-commanding antecedent. According to principle C, R-expressions do not tolerate any c-commanding antecedent in any domain. Different approaches elaborating on the classical binding theory have been proposed; see Reuland (2011), Rooryck and Vanden Wyngaerd (2011) for recent general assessments. Among the approaches addressing principle C, most of them, such as Grodzinsky and Reinhart (1993), Reinhart (1983), Schlenker (2005), while varying considerably in implementation, share reliance on the configurational relation of c-command, which is the critical feature for our discussion. Throughout the paper we will drastically simplify complex analytic issues by using the term ''syntactic approaches'' to refer to approaches crucially relying on c-command, and by framing our discussion in terms of classical binding theory.

Classical Principle C encompasses both cases in which a c-commanding pronoun cannot be the antecedent of an R-expression (**He** likes **John**; **He** thinks that **John** is crazy) and cases in which an R-expression cannot bind an identical R-expression (**John** likes **John**; **John** thinks that **John** is crazy). So, the possibility of identical repetition is excluded by principle C when one of the R-expressions c-commands the other as in (1)b, excluded on a par with (1)a, in which an R-expression is c-commanded by a pronoun.

Importantly, however, there are cases of identical repetition that sound infelicitous, in which neither occurrence of the R-expressions c-commands the other, and hence they are not excluded by principle C. This involves cases like (2) (see Chomsky and Lasnik, 1993, pp. 96–97, for similar examples).

(1) a. He_i thinks that $John_i$ is nice.
b. $John_i$ thinks that $John_i$ is nice.

(2) When $John_i$ watched TV, $John_i$ ate sunflower seeds.

It seems that repetitions like the one in (2) would be marked as deviant by a different class of considerations, reminiscent of the rhetorical type anaphora mentioned at the outset. In other words, these expressions are deviant unless the speaker wants to create a particular rhetorical effect, as in the famous Shakespearian quote in (3):

(3) ''But Brutus says he was ambitious;
and Brutus is an honourable man.''

Shakespeare, *Julius Caesar*, Act III, Scene 2

The use of a pronoun instead of repeating an R-expression presupposes that the speaker and the hearer share information, and that the hearer would have enough information to identify the referent of the pronoun. In the relevant cases, a discourse principle appears to be in action, which induces the speaker to use the lightest expression, with the least amount of semantic-lexical information that would allow the hearer to identify the referent: a ''Go Lighter'' principle. Work on such principle in the formal linguistic tradition stems from Chomsky's (1981) Avoid Pronoun Principle, worked out in terms of the hierarchy introduced by Cardinaletti and Starke (1999), and in Burzio's (1991, 1996) approach to anaphor binding. In this work we will use the term ''Go Lighter'' principle in the aim to bridge this aspect of the formal linguistic tradition with the psycholinguistic one referred to above.

Such principle would assume a hierarchy in which full referring expressions and proper names are higher in the hierarchy, being more richly specified, than overt pronouns, which are, in turn, higher than anaphors and null elements. Thus, when the speaker is confronted with a situation in which she can use a pronoun or a full referential expression, she will prefer to use the pronoun by the Go Lighter consideration.

This holds not only in complex sentences like (2), but also across discourse exchanges, as in the dialog in (4).[1]

[1] Other factors may modulate the acceptability of repetitions over and above rhetorical effects. E.g., in contrastive environments the repetition is fine: if the question involves a choice between two referents, e.g., ''What did John and Bill do?'' a felicitous answer would be ''John left (and Bill remained at home)''.

(4) Q: What did John do?
A: John left
The felicitous answer would rather involve the pronoun, as in *He left*.

Thus, the compliance with the Go Lighter principle goes beyond sentence grammar and is checked against a background of shared knowledge[2] between the speaker and the hearer on what referents are presupposed, and which referents are new and need to be introduced for the first time in a particular discourse or conversational exchange. When the speaker answers a question like (4)Q, she is aware that John is a salient referent for her interlocutor, hence in her reply she can refer to him using a pronoun, and must do so under Go Lighter.

Thus, we suggest a disentangling approach according to which the use of referring expressions obeys two types of guidelines. One follows formal structural conditions, the other is in terms of a discourse principle arguably connected to shared knowledge. Therefore, looking at the sentences in which the repetition of referential expressions is deviant, one has to distinguish two possible sources of deviance. One is the relevant case of the purely syntactic principle C, ruling out configurations in which c-command holds between the two identical R-expressions, the other is the Go Lighter economy principle, based on shared knowledge, applying also in environments in which c-command does not hold, and in discourse. For example, sentences like (1)b above involve a c-command relation between the two occurrences of *John*, hence they are ruled out by principle C (and also by Go Lighter: see fn. 3). Sentences like (2) are solely made deviant by the Go Lighter principle, unless some rhetorical effect of anaphora in the traditional sense is intended as in the Brutus sentences (see also fn. 1).[3]

In the current study we use a new angle to test this disentangling approach. We test individuals after brain damage who can apply the syntactic principles, but not the shared-knowledge considerations, and explore the way they treat repeating DPs in different configurations. Under the hypothesis that a proper application of Go Lighter is modulated by considerations of shared knowledge, the disentangling approach would expect them to be able to rule out sentences like (1)b using the c-command configuration and principle C, but to have difficulties when perceiving the deviance is only based on the computation of shared knowledge and the consequent compliance with the Go Lighter principle (like (2)). Whereas cases like (1)b are excluded for non-aTOMic speakers by both syntactic and discourse factors, they would be solely excluded for aTOMic speakers by the syntactic principle. Before we present the examination of such individuals, we describe what is currently known about the impairment in evaluating other people's knowledge states, and the relation between this impairment and language.

1.1. Theory of Mind and reference in discourse

Theory of Mind can be broadly defined as the ability to stand in other persons' place and see the world through their eyes. This ability allows one to understand that others hold mental beliefs, desires, emotions, and intentions that may differ from his own, and which motivate behavior (Apperly, 2011; Happé et al., 1999; Martín-Rodríguez and León-Carrión, 2010; Muller et al., 2010).

The ability to take part in conversation is directly related to TOM. The crucial link between TOM and the capacity to hold a proper conversation is the need to consider others' point of view and the knowledge that is shared between the speaker and the hearer (Grice, 1989; Sperber and Wilson, 1995, 2002). To succeed in TOM tasks one needs to consider the information that others have access to, the thoughts and feelings they hold, and the behavior they will exhibit accordingly. In order to engage in meaningful discourse there is a parallel need to ''read the mind'' of the interlocutor and to tailor the utterance according to her understanding and informational needs (Champagne-Lavau and Joanette, 2009; Happé, 1994; McDonald, 2000; Shamay-Tsoory et al., 2005; Winner et al., 1998).

[2] In the current research the notion of 'shared knowledge' refers to the knowledge that the speaker and the hearer assume their conversation partner is holding according to the developing speech situation (as discussed by Hawkins, 1978, 1991) and is relevant to the analysis of the way reference terms are analyzed according to Prince (1981, 1992), Sperber and Wilson (2002) and following Ariel (1990), Clark and Wilkes-Gibbs (1986) and Gundel et al. (1993).

[3] The deviance of (1)a is perceived as stronger than the deviance of (1)b. This is plausibly related to the observation due to Lasnik (1989), chapter IX, that in some languages sentences like (1)b are in fact possible whereas sentences like (1)a are systematically ruled out. This suggests that UG offers a device to circumvent principle C in cases like (1)b and this may affect the relative unacceptability also in languages that do not explicitly adopt the relevant parametric option. Notice that the distinctions between a repetition which violates principle C and a repetition which simply violates Go Lighter are also perceived in terms of relative unacceptability. E.g., Chomsky and Lasnik (1993) mark cases like (1)b as ''*'' and cases like (2) as ''?''. A disentangling approach is thus made immediately plausible by the distinction in the degree of deviance. It can also be observed that a sentence like (1)b violates both Principle C *and* Go Lighter, a fact that in and of itself could be deemed responsible for the perceived stronger deviance of (1)b compared to (2).

One crucial domain in which TOM is required in discourse is the choice of appropriate reference terms. Speakers use various reference terms to direct their addressee's attention to entities mentioned during the discourse. The speakers' task is to choose which term to use according to their assessment of their addressees' familiarity with the referents mentioned and the shared knowledge about them created during the conversation. The hearers' task is to correctly pick out the intended referent using these reference terms while considering the speakers' discourse representation (Sperber and Wilson, 1995, but see Breheny, 2001, Pickering and Garrod, 2004, for critical analysis of the processes). To allow the hearer to correctly choose an intended referent from the context, the speaker uses highly informative terms. Typically, new referents are introduced in discourse using a full noun phrase (sometimes with a relevant description). Once a character is introduced and as long as it is the topic of the discourse and there are no other competing entities, it is expected to be very accessible to the hearer. Therefore it is referred to using relatively less-informative expressions like pronouns (Ariel, 1990, 2001). The task of choosing the appropriate term critically relies on the ability to evaluate shared knowledge. Studies of typically developing children who have not fully acquired TOM yet and of individuals with autism indicate that these individuals show specific difficulties in discourse that are related to their TOM inability (typical development: de Villiers, 2007; Gundel et al., 2007; Milligan et al., 2007. ASD: Arnold et al., 2009; Nadig et al., 2009). TOM impairment can also occur as an acquired disorder. Acquired TOM impairment, *aTOMia*, has been mainly studied in adults who suffered brain damage in the right frontal and temporal brain areas (Amodio and Frith, 2006; Frith and Frith, 2003, 2006) and patients after traumatic brain damage (Geraci et al., 2010; Havet-Thomassin et al., 2006; Milders et al., 2006; Muller et al., 2010). The exact role of each of the brain areas in various aspects of TOM is yet to be defined (Apperly, 2011). Some studies highlight the medial prefrontal cortex (MPFC) as the locus of TOM reasoning (Amodio and Frith, 2006; Brunet et al., 2000; Frith and Frith, 2003, 2006; Gallagher et al., 2000), others point to a more posterior location – the temporo-parietal junction (TPJ), especially the right TPJ, as the location specifically dedicated to attributing thoughts (Aichhorn et al., 2008; Saxe and Powell, 2006; Saxe and Wexler, 2005).

Importantly, many patients after right hemisphere damage and traumatic brain injury show difficulties in various TOM abilities, and accordingly, have difficulties in language domains that require TOM. Studies reported that they suffer difficulties in discourse understanding (Blake, 2006, 2007), and characterize their contribution to conversation as tangential and egocentric, irrelevant, off topic or incorrect, centered on isolated details and digressive (Blake, 2006). They have difficulties in articulating requests (Brownell and Stringfellow, 1999), appreciating jokes and sarcasm (Chanon et al., 2007; Cheang and Pell, 2006; McDonald, 2000) and in attending to implicit details in stories (Ferstl et al., 2005).

In a recent study, Balaban et al. (2008) and Balaban and Friedmann (2010) tested 25 Hebrew-speaking individuals with right hemisphere damage, of which 17 had aTOMia. They found that the participants who had aTOMia also showed significant difficulties in TOM-related language abilities, including the use of pronouns, referring expressions, and definite articles, whereas their pure syntactic abilities remained intact. The aTOMic participants in Balaban et al.'s study showed difficulties both in production and in judgment of sentence appropriateness. In a story-retelling task, the total percentage of noun phrases the aTOMic participants used in their recall was almost identical to that of a control group (approximately 20%) but the distribution of proper names and pronouns was different. Many of the noun phrases that the aTOMics produced did not allow for a clear identification of their reference. This property differed significantly between the aTOMic individuals, who produced only 77% noun phrases with clear reference (SD = 14%) and a control group of right brain damaged patients with good TOM (M = 97%, SD = 3%). The most frequent error of the aTOMic participants (82% of the errors) was overuse of pronouns instead of full noun phrases, which did not allow appropriate reference assignment. In another task, the aTOMic participants were asked to choose which of two sentences were more appropriate to continue a conversation between two interlocutors. The difference between the two options was the amount of information included in the noun phrases. The conversations were either between two characters that was well acquainted (e.g., mother and daughter) or between new acquaintances (e.g., a new employee and his boss). For the conversations between well acquainted speakers who shared much common knowledge there was need to add little information to convey the message, therefore the less informative nominal expressions were appropriate. For conversations between speakers who did not share much common knowledge a greater amount of information was needed to allow for proper continuation of the conversation. Balaban et al. found that the aTOMic participants did not choose referring expressions according to the difference between familiarity statuses of the conversers. They chose the inappropriate expressions in both situations significantly more than non-aTOMic brain damaged control participants and healthy control participants. The same pattern of results was found when the aTOMic participants' ability to distinguish between the conditions in which they should use definite or indefinite noun phrases was examined. In production, the aTOMic participants were significantly less precise in varying the use of definite and indefinite noun phrases according to whether the noun phrase appeared earlier in the context. The same was found in a judgment task, where the aTOMics were not sensitive to the creation of shared knowledge and judged the ending sentences as appropriate in cases the noun phrase was not marked appropriately by a definite article, significantly more than non-aTOMic participants.

Thus, to examine the disentangling approach, in the current study we tested a group of brain-damaged patients who had aTOMia, as indicated by their poor performance in a battery of tasks that test various aspects of TOM (the aTOMia

battery, Balaban et al., 2008, 2010). We tested their pure syntactic abilities on tasks of comprehension of reflexives and pronouns, and then tested their judgment and interpretation of sentences with repetition of full DPs, which are either ruled out by principle C, i.e., under c-command, or by a Go Lighter principle.

The rationale was that if these participants show impaired TOM and good syntactic abilities, including good abilities in the comprehension of principles A and B, their performance on the sentences ruled out by principle C should be better than their performance in sentences that require computation of shared knowledge as in the Go Lighter principle, and for which configurational principles do not mark their deviance.

An alternative to the disentangling approach would be to assume that all cases of repetition of referential expressions are made deviant by a single discourse-economy principle of the Go Lighter kind (i.e., not referring to c-command). Such an approach would treat the repetition in sentences like (1b) and (2) on a par.

An example for such an approach is Harris and Bates (2002), who suggested that people do not need to know c-command to interpret pronouns, and that all generalisations that linguists formalize in structural terms can be cast in cognitive terms. One can see this approach also in research that tested ''repeated name penalty''. Swaab et al. (2004), for example, compared the repetition of nouns in sentences where this repetition is dispreferred and sentences where this repetition is acceptable. Swaab et al. ascribed such differences in acceptability to pragmatics, and suggested that ''. . .the difficulty in processing repeated names could be construed as a pragmatic phenomenon where the provision of too much information causes the reader to expend some processing resources in trying to determine why apparently unnecessary information was presented'' (p. 722). According to such discourse-only approaches, people with problems in TOM would be expected to fail to reject both kinds of sentences.

In the current study, Experiment 1 (described in Section 3) was designed to test the ability of individuals with TOM impairment to comprehend reflexives (himself/herself) and pronouns (him/her) according to binding principle A and principle B. This test was included to ensure that TOM impairment does not affect the ability to perform reference resolution in complex sentences comprehensively, and also to test the ability of patients with TOM impairment to compute the c-command relation, which is crucially involved in binding.

We then tested in two experiments the two principles, C and the Go-Lighter principles, on these patients' judgment and comprehension of sentences that include repetition of referential expressions, which are ruled out either on the basis of discourse considerations or on the basis of the syntactic principle (Experiments 2 and 3).

2. Participants: Experiments 1 and 2

We included in the study all consenting individuals present in the three major rehabilitation centers in central Israel during the three years of the study who met the following criteria: Hebrew-speaking (monolingual or Hebrew-dominant), had right hemisphere brain damage or traumatic brain injury (TBI): None of the participants was diagnosed as aphasic and none of them was treated by a speech pathologist for language difficulties (see below for details regarding their syntactic abilities).

We approached patients with these types of brain injuries because individuals with right hemisphere damage and traumatic brain damage are often reported to have TOM impairment (Blake, 2006, 2007; Champagne-Lavau & Joanette, 2009; Dahlberg et al., 2006; Havet-Thomassin et al., 2006) and asked for their consent to participate. We had no information about their TOM abilities prior to the study. Because the aim of this study was to examine the possible connections between TOM abilities and specific linguistic competence, the participants were classified according to their performance on the battery of TOM tasks.

A group of 31 brain damaged patients, 10 women and 21 men, took part in Experiments 1 and 2 (see Table 1). Their mean age was 44 years (ranging between 18 and 66 years, SD = 14.3). Sixteen of the participants had right-hemisphere stroke, for two the brain damage was following a surgery for the removal of a right parieto-frontal-temporal tumor (Sachar), or a right frontal cavernoma surgery (Gila), and 13 patients suffered traumatic brain injury due to accidents. Twenty-nine of the participants were native Hebrew speakers. The two who were not native speakers of Hebrew (Dror and Rachel) spoke the language for more than 57 years prior to the brain damage. All the participants were tested at least 2 months post onset. Their results were compared to a group of 19 healthy adults, aged between 37 and 66 (M = 49.10, SD = 11).

To evaluate the TOM ability of each of the participants, we administered the aTOMic battery (see Balaban et al., in press, for a detailed description of each of the tasks), a comprehensive test of Theory of Mind, comprised of 8 categories, two items in each category. The battery included items testing first order false belief, 2nd order false belief, understanding knowledge gaps, understanding scenarios in which teaching was initiated, understanding white lies, embarrassing social situations, and cartoons with TOM. The items were presented in a semi-random order. They were placed on the desk in front of the participants, and were read to them by the experimenter, as many times as requested. The same experimenter read the items to all participants.

The first question that we asked about each item was a fact question. The fact questions were used to verify that the participant listened, remembered, and understood the events in the story. If an incorrect answer was given, the item was

Table 1
Background information on the participants with brain damage.

	Gender	Age	Spoken language	Education	Handedness	Lesion site and etiology	TOM score (%)
Motty	M	66	Hebrew	High School	R	TBI, multiple fracture of facial bones.	14
Micha	M	18	Hebrew	High School	R	TBI, several small intraparenchimal hemorrhages consistent with diffuse axonal injury, small fracture of the left occipital condyle.	14
Noam	M	33	Hebrew	High School	R + L	TBI, Diffused axonal injury.	21
Tzipora	F	60	Hebrew	High School	R	Ischemic infarct in the right MCA territory.	26
Dafna	F	50	Hebrew, English	High School	R	Ischemic CVA Pones.	32
Abraham	M	52	Hebrew	High School	R	Ischemic infarct in the right MCA territory.	36
Arye	M	48	Hebrew	High School	R	Ischemic stroke with hemorrhagic transformations right MCA.	37
Dror	M	64	Hebrew, Arabic	High School	R	Ischemic infarct involving right fronto-temporal-parietal areas.	41
Jacob	M	51	Hebrew	High School	R	CVA-Ischemic stroke (Thalamus, Internal Capsule)	47
Yigal	M	54	Hebrew	High School	R	Recurrent right ischemic infarct involving frontal areas and the Corona Radiata.	50
Yoel	M	57	Hebrew	Academic	R	TBI, bilateral prefrontal contusions, bilateral subarachnoid hemorrhage, right parietal subdural hematoma, leftward midline shift, open fracture of the occipital bone.	50
Daniel	M	55	Hebrew, Arabic	High School	R	Ischemic infarct in the territory of the right MCA, complete block of right ICA.	58
Sachar	M	36	Hebrew	High School	R	Craniotomy for removal of right parieto-frontal-temporal tumor.	59
Rachel	F	62	Hebrew, English, Arabic	High School	R	Right Frontal ischemic infarct.	64
Gila	F	56	Hebrew	High School	R	Right Frontal covernoma – Craniotomy and evacuation of intra cerebral right frontal hematoma CVA Ischemic Infarction in right Capsular Putaminal and right thalamic regions.	68
Gady	M	30	Hebrew	Academic	R	TBI, early CT showed small right frontal contusion, and a small posterior falx subdural hematoma. Follow up study demonstrated small frontal subdural hygroma.	77
Donny	M	45	Hebrew	High School	R	TBI, left temporal linear fracture, hemosinus involving the sphenoid and frontal sinus.	80
Yaron	M	46	Hebrew	High School	R	Ischemic infarct involving the Right Corona Radiata.	84
Sally	F	20	Hebrew	High School	R	TBI	86
Tzvi	M	25	Hebrew	Academic	R	Ischemic infarct in the territory of the right MCA, with brain edema and pending herniation.	90
Adam	M	34	Hebrew	High School	R	TBI, right Epidural hematoma, left subdural hematoma, right prefrontal contusion and subarachnoid hemorrhage. Multiple fractures of the facial bones, fracture of the right temporal bone involving the pyramid.	91
Ofer	M	26	Hebrew	Academic	R	TBI, left fronto-temporal epidural hematoma, multiple fractures of base of skull, left zygoma and orbit. Post-craniotomy CT demonstrated right frontal intracerebral hematoma.	92
Tali	F	21	Hebrew	High School	R	TBI, intraventricular hemorrhage, more prominent in the left lateral ventricle.	92
John	M	50	Hebrew	High School	R	TBI, right frontal contusion, subarachnoid hemorrhage, fracture of base of skull.	93
Yotam	M	42	Hebrew	Academic	R	TBI, left-parietal subarachnoid hemorrhage. Hemorrhage in the Pones and white matter.	93
Moshe	M	59	Hebrew	High School	R	Subacute infarct in the right hemisphere, adjacent to the internal capsule, caudate body, across to the Globus Pallidus.	94

Table 1 (*Continued*)

	Gender	Age	Spoken language	Education	Handedness	Lesion site and etiology	TOM score (%)
Sigalit	F	62	Hebrew, English	Academic	L	Right occipital infarct. Spontaneous intraparenchimal hemorrhage.	95
Sharon	F	38	Hebrew, English	High School	R	Ischemic infarct in the territory of the right MCA.	100
Ahuva	F	32	Hebrew	High School	R	Ischemic infarct in the territory of the right MCA.	100
Karin	F	28	Hebrew	Academic	R	TBI, diffused axonal injury.	100
Ayal	M	47	Hebrew	Academic	R	Ischemic infarct in the territory of the right MCA. Right periventricular infarct.	100

The participants in the aTOMic group appear on shaded background.
TOM scores are percentage correct in the aTOMic battery.

read again or a clarifying remark was added. Next, we presented a yes/no TOM question and then asked for a justification of the reply. In coding the justifications we considered the participants' reference to shared knowledge or knowledge gaps between the protagonists. An item was considered correct only if the participant gave both a correct yes/no answer and an appropriate justification (see Appendix A for an Example item).

The control group scored well on the TOM battery ($M = 94.7\%$, SD = 6.8%). The performance of the brain damaged participants in the aTOMic battery, summarized in Table 1, indicated that 15 of the participants had a severe deficit of TOM (aTOMia), with scores ranging between 14% and 68% correct ($M = 41.2\%$, SD = 16.8%), each performing significantly poorer than the control group ($p < .05$, Crawford and Howell's *t*-test). Sixteen other participants with brain damage had good TOM abilities, which did not differ significantly from that of the healthy controls, with scores ranging between 77% and 100% correct ($M = 91.7\%$, SD = 7.1%), all but four of them performed at a level above 90% correct.

The **syntactic** abilities of the participants[4] were tested using tasks that were found to be sensitive to syntactic impairments in aphasic patients: comprehension of relative clauses and comprehension of Wh questions (Friedmann, 2008; Friedmann and Shapiro, 2003; Grodzinsky, 1989; Grodzinsky et al., 1999) (see Appendix B for a detailed description of the tasks). Each of the participants participated in at least one test assessing their processing of sentences with Wh-movement. Comprehension of subject- and object relatives was assessed using a sentence-picture matching task, selecting between two pictures, each with two figures (this test was previously used and described in Friedmann, 1998; Friedmann and Shapiro, 2003). Comprehension of Wh questions was assessed using a picture selection task with three figures (a test previously used and described in Friedmann et al., 2009; Friedmann and Novogrodsky, 2011; Friedmann and Szterman, 2011). The performance of the participants with aTOMia on the two tasks was high. Each of them performed above 85% correct. The group's average performance on comprehension of object relative clauses was 91.8% correct (SD = 7%), and in Wh object question comprehension it was 98.2% correct (SD = 5%). Thus, one can conclude that despite their brain damage, and for the patients who had aTOMia also despite their aTOMia, their syntactic abilities remained intact, and they performed well on the purely syntactic tasks. (The participants without aTOMia scored 100% correct on Wh-object-question comprehension and 99.7% correct (SD = 1.3%) on the comprehension of object relative clauses.)

In the current study we are interested in the ability of these patients to properly use referring expressions, and to apply principles of different nature. Specifically, we are interested in determining whether they show different patterns of performance with respect to referring expressions that are regulated by syntactic principles and those that are regulated by a discourse principle such as the Go Lighter principle. To examine this question, we first tested the patients' performance with respect to the binding principles A & B, the syntactic principles regulating the distribution and interpretation of anaphors and pronouns (**Experiment 1**). We then tested their performance with respect to the syntactic principle C and compared it to their performance in the Go Lighter situation, using two experiments: one that assessed their sentence preference (**Experiment 2**), and one that assessed their sentence interpretation (**Experiment 3**).

3. Experiment 1: Binding Principles A & B

We started by establishing the preserved syntactic abilities of the brain-damaged participants within the binding domain. We tested their knowledge of principles that determine the use of reflexives and pronouns, which are closely related to the principles that dictate the use of R-expressions and which require sensitivity to c-command. The distribution

[4] The syntactic tests were administered to all but three of the participants. Rachel, Yigal, and John were not tested in these syntactic tests because they were no longer available for testing when we administered the syntactic tests.

and interpretation of reflexives and pronouns are governed by binding principles A and B, respectively. These binding principles were found to be sensitive to syntactic difficulties, such as in the case of people with an acquired language impairment, agrammatic aphasia (Baauw and Cuetos, 2003; Baauw et al., 2011; Edwards and Varlokosta, 2007; Grodzinsky et al., 1993; Ruigendijk et al., 2006, 2011; Vasić, 2006), and in children in the process of language acquisition (cf., the so-called Delay of Principle B Effect reported in Baauw et al., 2011; Chien and Wexler, 1990; Grodzinsky and Reinhart, 1993; Thornton and Wexler, 1999, and others, but see Conroy et al., 2009 for critical assessment). In Hebrew, for instance, typically-developing children who were tested with the same task that we use below were found to still allow a local antecedent for pronouns until around the age of 6. For example, they point to a picture of a girl pinching herself when they hear the sentence ''The grandma said that the girl pinched her'' (Friedmann et al., 2010a,b; Ruigendijk et al., 2010).

Therefore, if our participants have an impairment in the syntactic binding principles, they should fail in the current experiment. If, however, their syntactic ability is normal, they should interpret the sentences with reflexives and pronouns correctly.

3.1. Procedure and material

The application of Binding Principles A & B in comprehension was tested using a sentence-picture matching task (Friedmann et al., 2010a,b; Ruigendijk et al., 2010). The test included 72 sentences, half with a pronoun and half with a reflexive. The test included 24 coordinated sentences ('The girl and the grandma met and then the girl pinched herself/her'), 24 were sentences with a sentential complement ('The grandma said that the girl is pinching herself/her'), and 24 were relative clauses ('The girl that met grandma pinched herself/her'). The two DPs in each sentence always had the same gender in order to preclude gender agreement cue for the choice of the antecedent. The sentences were presented together with one page that included two pictures, one matched the sentence and the other presented an incorrect antecedent (the other DP in the sentence) as the object, as shown in Fig. 1.

3.2. Results

All the brain damaged participants, in both groups, performed almost perfectly on this task. Each of them performed above chance level. The detailed results appear in Table 2. No significant differences were detected in either principle A or principle B comprehension between the groups, U = 87.5, p = .10; U = 82, p = .07, respectively.

Fig. 1. Example of a picture pair in the pronoun and reflexive comprehension task (Experiment 1).

Table 2
Performance of the aTOMic and good-TOM individuals with brain damage in the pronoun and reflexive (principles A and B) task (average percentage correct and SD).

	A – reflexives	B – pronouns
aTOMic	98.3% (2.7%)	95.7% (6.1%)
Good TOM	99.5% (1.5%)	99.0% (2.4%)

4. Experiment 2: disentangling approach for repeating expressions put into test

After establishing that the patients had good control of the principles governing the distribution of reflexives and pronouns, we continued to put into test the disentangling hypothesis, according to which there are two different factors governing the appearance of repeating expressions. Thus, in this task we tested whether the participants could rule out repetition of referring expressions and prefer a pronoun over a repetition in two conditions: when the formal syntactic condition of principle C and c-command rule out repetition, and when mere shared knowledge considerations disfavor repetition under the Go Lighter principle.

4.1. Method and materials

In each item the participant was asked to choose between two sentences. In each of the sentences a referent appeared twice, the first occurrence was a proper name. In one sentence the second occurrence was a repetition of the proper name (5a), and in the other sentence the second occurrence was a pronoun (5b).

(5) a. Tami nirshema le-veit-sefer le-ginun mikeivan she-Tami ohevet ecim u-fraxim.
Tami registered to-school for-gardening because that-Tami loves trees and-flowers.
''***Tami*** *registered to a gardening school because* ***Tami*** *loves trees and flowers.*''
b. Tami nirshema le-veit-sefer le-ginun mikeivan she-hi ohevet ecim u-fraxim.
Tami registered to-school for-gardening because that-she loves trees and-flowers.
''***Tami*** *registered to a gardening school because* ***she*** *loves trees and flowers*''

We asked the participants: ''Which sentence sounds more felicitous, sounds better, more natural in conversation?''

We used two main conditions: seven sentences such as (5), in which principle C does not apply, because the repeated proper names were not in a c-command configuration, so the choice not to repeat was guided by the Go Lighter principle; and two sentences in which the two occurrences of the same proper name were in a c-command configuration, and hence the choice was determined by principle C, as in (6a,b) and (6c,d).

(6) Principle C violation:
a. Yoram raca li-knot le-Ruty matana lifney she-Ruty ozevet le-tafkid xadash.
Yoram wanted to-buy to-Ruthie gift before that-Ruthie leaves to-job new.
''Yoram wanted to buy **Ruthie** a gift before **Ruthie** leaves for a new job''.
b. Yoram raca li-knot le-Ruty matana lifney she-hi ozevet le-tafkid xadash.
Yoram wanted to-buy to-Ruthie gift before that-she leaves to-job new.
''Yoram wanted to buy **Ruthie** a gift before **she** leaves for a new job''.
c. Tali Bachar hivtixa le-Tali Bachar lo le-ashen yoter.
Tali Bachar promised to-Tali Bachar not to-smoke anymore.
''**Tali Bachar** promised **Tali Bachar** not to smoke anymore''.
d. Tali Bachar hivtixa le-acma lo le-ashen yoter.
Tali Bachar promised to-herself not to-smoke anymore.
''**Tali Bachar** promised **herself** not to smoke anymore''.

Notice that in (5a,b) and (6a,b) we take two adjunct clauses to illustrate, respectively, the no-c-command condition and the c-command condition. This is legitimate due to the different level of attachment of *because* and *before* adjunct adverbials, the latter being lower than the former in the clause structure. Straightforward evidence for a difference in attachment is provided by the fact that in the sequential order *before* clauses precede *because* clauses. This is illustrated by the Hebrew examples in (7)a and (7)b. Whereas (7)a, with order *before – because*, is perfectly natural in the interpretation in which both adjunct clauses modify the main clause, the order *because – before* in (7)b appears to force the interpretation in which the *before* clause is embedded in the *because* clause. This ordering property follows if the *because* clause is attached higher up in the tree:

(7) a. Ha-muzikai lo lamad be-al-pe et keta-hagez [lifnei she-hu nixnas l-a-ulam] [ki hu raca le-alter]
The musician not learn by-heart ACC the-jazz-piece [before that-he entered to-the-hall] [because he wanted to-improvise]
''The musician did not learn the jazz piece by heart [before he entered the hall] [because he wanted to improvise]''
b. Ha-muzikai lo lamad be-al-pe et keta-hagez [ki hu raca le-alter lifnei she-hu nixnas l-a-ulam]
The musician not learn by-heart ACC the-jazz-piece [because he wanted to-improvise before that-he entered to-the-hall]
''The musician did not learn the jazz piece by heart [because he wanted to improvise before he entered the hall]''[5]

What is critical for determining that principle C applies in structures with *before* as in (6a,b) but not in structures with *because* as in (5), is that *because* clauses can be attached high enough not to be c-commanded by the subject or other clause internal arguments, while *before* clause are attached lower down, in a position c-commanded by clause-internal arguments. Clear evidence supporting this different level of attachment comes from the licensing and interpretation of a null subject in the adjunct clause in Hebrew. Hebrew, a partial null subject language, permits a referential *pro* in embedded clauses in certain tenses when it is c-commanded by an antecedent, which identifies it (Shlonsky, 2014, and much related work). *Before* and *because* clauses sharply differ in this respect:

(8) a. Shti et ha-xalav od hayom, lifnei she-*pro*-yaxmic
Drink the-**milk** already today, before that-***pro***-gets-sour
b. *Shti et ha-xalav od hayom, mikeyvan she-*pro*-yaxmic
*Drink the-**milk** already today, because that-***pro***-gets-sour
b'. Shti et ha-xalav od hayom, mikeyvan she-hu-yaxmic
Drink the-**milk** already today, because that-**he**-gets-sour

The null subject in the *before* clause is c-commanded (and identified) by the direct object in (8)a, while a null subject in the *because* clause in (8)b is too high in the hierarchical structure to permit this kind of identification (and hence a full pronoun is required, as in 8b').

Furthermore, one can see in (9) that the *because*-clause is higher than the subject, since *pro* cannot be identified by it:[6]

[5] A Principle C effect also arises in cases in which the pronoun precedes the noun phrase antecedent. For instance, there is a clearly detectable difference in acceptability in Hebrew between a sentence like (i), which is a Principle C violation, and a sentence like (ii), which is not:

i. *Hu lo lamad be-al-pe et keta-hagez [lifnei she-ha-muzikai nixnas l-a-ulam] [ki hu raca le-alter]
he not learned by-heart ACC the-jazz-piece [before that-the-musician entered to-the-hall] [because he wanted to-improvise]
*''**He** did not learn the jazz piece by heart [before **the musician** entered the hall] [because he wanted to improvise]''
ii. Hu lo lamad be-al-pe et keta-hagez [ki ha-muzikai raca le-alter lifnei she-hu nixnas l-a-ulam]
He not learned by-heart ACC the-jazz-piece [because the musician wanted to-improvise before that-he entered to-the-hall]
''**He** did not learn the jazz piece by heart [because **the musician** wanted to improvise before he entered the hall]''

Notice that while acceptable, (ii) is however felt unnatural, and therefore we preferred the other, more natural sentence test above. In general, sentences in which the pronoun precedes the full noun phrase antecedent are somewhat awkward if the referent of the pronoun is not previously introduced.

[6] Further evidence that *before* clauses are merged lower than *because* adverbials comes from the interaction with negation: *before* clauses are necessarily merged in a low position, lower than negation, as shown by the fact that the negative island effect arising when the adjunct clause is clefted, as in (i)b. In contrast, *because* adverbials can be interpreted outside the scope of negation, as is shown by the ambiguity of (ii)a and by lack of negative island effects as in (ii)b. Thus, *because* clauses can be merged in a position higher than negation, and interpreted outside its scope (Rizzi, 1990):

i. a John didn't come before Mary left
b *It's before Mary left that John didn't come
ii. a John didn't come because Mary left
b It's because Mary left that John didn't come

Analogous kinds of evidence for a distinct level of attachment can be found in Hebrew for *because* and *before* adjunct clauses. E.g., *iii* has ambiguous scope, whereas *iv* does not

iii. Yoni lo ba ki hu raca leexol
Yoni not came because he wanted to eat
iv. Yoni lo ba lifnei she-hu axal
Yoni not came before that he ate

This supports the hypothesis of a different attachment of the adjuncts in Hebrew as well. This conclusion is consistent with the hypothesis that the main subject necessarily c-commands the embedded subject in (6a,b), but not in (5). Notice also that example (6c,d) unquestionably involves c-command of the subject DP over the indirect object.

(9) a. ha-xalav xayav le-hishatot lifnei she-*pro*-yaxmic
The milk must be drank **before** that-*pro*-gets-sour
b. *ha-xalav xayav le-hishatot biglal she-*pro*-yaxmic
The milk must be drank **because** that-*pro*-gets-sour

Going back to our stimuli in (5)–(6), we notice that in sentence (6)c the second proper name is in the same simple clause as the first (which c-commands it), hence it alternated with an anaphor (6)d; in (6)a, the second proper name occurs in an embedded clause, hence it alternates with a pronoun (6)b.

In addition to these 9 test items, we included 4 filler items with semantic infelicity (10) or syntactic ungrammaticality that involved word order, tense, or reflexive pronoun use (11).

(10) a. I love to drive the car while my father is driving it.
b. I love to ride the car while my father is driving it.
(11) a. John thinks that Mary likes him.
b. *John thinks that Mary likes himself.

The test items were presented in a semi-randomized order after two practice items. The experimenter read each item in normal intonation and pace, and re-read them if necessary. The written sentences were presented to the participants. The participants were encouraged to read the sentences themselves or to look at the sentences while the experimenter was reading the sentences to them.

An answer was coded correct if the participant chose the sentence with the pronoun, and incorrect if s/he chose the sentence with a repetition of a proper name or if s/he replied that there was no difference between the sentences.

4.2. Results

In marked contrast to their good performance in the test that required the application of syntactic binding principles with respect to pronouns and reflexives, the aTOMic participants showed a considerable impairment when they came to evaluate the distribution of full noun phrases. Crucially, however, their difficulty manifested itself only when principle C could not protect them, namely, when the two noun phrases were not in a c-command configuration.

The two sentences in which principle C rules out repetition of the proper name were judged in accordance to the principle by most aTOMic participants (M = 90.0% correct). Only 3 of the 15 aTOMic patients erred in one of the two items that required principle C. In contrast, in the condition in which Go-Lighter would be the only factor disfavoring repetition, 14 of the 15 aTOMics chose at least one item in which the DP was repeated. In fact, eight of these participants preferred to repeat the proper name on at least half of these sentences. The average percentage correct of the group of aTOMICs on the Go Lighter sentences (M = 49.8%) was significantly lower than their performance on the principle C sentences: T = 1, p = .002.

The detailed results appear in Table 3. On the principle C sentences, there was no significant difference between the aTOMics and the participants with good TOM (U = 104, p = .26), or between the aTOMics and the healthy control participants (U = 114, p = .17). Importantly, on the Go Lighter sentences the aTOMics scored significantly poorer than the participants with good TOM (U = 13.5, p < .0001) and significantly poorer than the control group (U = 17, p < .0001). The participants with good TOM and the control group did not differ on the Go Lighter items (U = 138, p = .33). These results are also consistent with a view according to which TOM is a continuum, and the better TOM abilities a person has, the more she rejects Go Lighter violations: there was a strong correlation between TOM and the performance on the Go Lighter items: r = .59, p = .0002.

Interestingly, there was a minimal pair of sentences with adjuncts, one involving ''before'', the other involving ''because''. Although superficially these sentences are very similar, one, the ''before'' adverbial, involves c-command by the subject, and therefore falls under principle C (see the discussion in Section 4.1), the other, ''because'' is only regulated by Go Lighter. And indeed the pattern of performance of the aTOMic participants on these two sentences was completely

Table 3
The average performance (and SD) of the individuals with brain damage in the principle C sentence selection task.

	Source for ruling out repetition		Fillers
	Principle C (N = 2)	Go Lighter (N = 7)	(N = 4)
aTOMic	90.0% (20.0%)	53.7% (27.1%)	96.7% (8.5%)
Good TOM	96.9% (12.5%)	94.9% (9.9%)	100% (0%)
Control (N = 19)	100% (0%)	96.5% (7.0%)	100% (0%)

different: 93% of the aTOMic participants ruled out repetition in the principle C context (*before* sentences), choosing the non-repeating sentence, but in the Go Lighter context (*because* sentences), the non-repeating sentence was chosen only by 60% of the aTOMics.

The control group strongly preferred to avoid repetition: out of 113 items that the control participants judged (one item was skipped), they preferred the pronoun over the repetition of the proper name in 109 items, and in 4 items they mentioned that both the pronoun and the repeated proper name were OK. Hence, the control participants did not prefer a repetition of the proper name over a pronoun in any of the items and they were very consistent in their preference. The fact that we used a preference task enabled us to highlight the clear preference for the non-repetition option that judgment of sentences in isolation would not be able to capture. Although speakers may contemplate the acceptability of sentences with repetition of the proper name in the Go Lighter context with no c-command, they consistently prefer the option with the pronoun.

On the filler sentences (detecting purely syntactic or semantic violations) all three groups performed very well. Thirteen of the 15 aTOMics performed 100% correct on the filler sentences. All the participants with good TOM abilities and the control group scored 100% correct.

5. Experiment 3: comparing principle C and Go Lighter using a picture selection task

Until now we assessed the preference between pairs of sentences regulated by principle C or by the Go Lighter principle. A different angle from which the respective role of the two principles can be assessed would be to investigate the way in which sentences with repetition are interpreted and understood by aTOMics and controls. We thus devised a new picture selection task, in order to examine the interpretation of sentences in the scope of principles C and Go Lighter, and to do so in a task that was similar to the one used to test principles A and B. We also tested here a different kind of violation of principle C that had not been tested in Experiment 2, a configuration in which a pronoun c-commands a full DP. Such sentences are usually considered the core case of violations of principle C.

5.1. Participants

For Experiment 3 we tested five additional native speakers of Hebrew with aTOMia following brain damage. Their performance on the aTOMic battery (Balaban et al., 2008, 2010, with the same procedure and coding described for the participants in Experiments 1 and 2), summarized in Table 4, indicates that all of them had poor TOM, with score ranging between 33% and 61%.

The control group included 10 adults (8 female and 2 male) with no known neurological impairment or language difficulties aged between 19 and 58 years (mean = 43, SD = 12.8).

5.2. Method and procedure

The sentence-picture matching test included 66 items. The main question of this study, that of disentangling repetitions ruled out by principle C and those ruled out by Go Lighter, was tested using 15 items testing Principle C (see examples (12–14)), and 15 items testing the Go Lighter principle (see examples (15) and (16)). The application of Binding Principles A and B was assessed using 30 items taken from the sentence-picture matching task that was used in Experiment 1. Fifteen items tested each of the 2 principles (Friedmann et al., 2010a,b; Ruigendijk et al., 2010). We also added 6 filler items, which were all Wh PP object questions (see example (17)).

Principle C was tested using two types of sentences. One type (11 items) included a pronoun c-commanding a full noun phrase, a configuration in which principle C dictates that the pronoun cannot refer to the same individual as the full noun phrase. The other type (4 items) included a repetition of the same full noun phrase in a c-command relation, where principle C dictates that the reference of the two should be different.

Table 4
Background information on the participants with right brain damage in Experiment 3.

	Gender	Age	Education (years)	Handedness	Lesion site and etiology	TOM score (%)
Aharon	M	60	12	R	Right middle cerebral artery occlusion	33
Shalom	M	45	12	R	Focal hemorrhage in the right parietal lobe	56
Yoni	M	57	10	R	Abrupt onset of left hemiplegia and speech difficulties (no lesion information from CT)	50
Tuvya	M	62	12	R	Vast right parieto-temporal infarct	43
Samson	M	56	12	R	Traumatic brain injury	61

Examples (12) and (13) show items testing sensitivity to principle C by evaluating the consequences of the principle for the interpretation of pronoun – DP configurations. Two characters are introduced with two full noun phrases, then the following sentence contains a pronoun c-commanding one of the two noun phrases. In examples like (12) the participants had to point to the referent of the pronoun: the correct answer to the question ''Who said that?'' was to point to the girl, because coreference between ''*she*'' and *the (feminine) bunny* was ruled out by principle C.

(12)

Hine arnevet ve-yalda. Hi amra she-ha-arnevet xamuda. Mi amra et ze?
Here's fem-bunny and-girl. She said that-the-feminine-bunny is cute. Who said that?

In examples like (13) the participants had to point to the matching picture; here the correct answer was to point to the first picture, with the boy holding the flower, because coreference between *he* and *Pierre* was proscribed by principle C.

(13)

Hine yeled, ve-cayar shekor'im lo Pier. Hu hexzik perax bazman she-pier ciyer.
here's a boy, and a painter named Pier. He held a flower while Pier was painting.

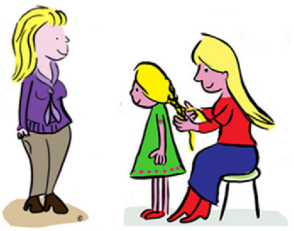
Example (14) tests the interpretive consequences of principle C in a configuration with two full DP's. A complex sentence contains two identical full DP's in a c-command configuration, and the question asked the participants to point to the referent of the higher DP. Under principle C, the two occurrences of the boy cannot refer to the same individual, hence the correct answer here would require pointing to the boy not being washed.

(14)

Ha-yeled amar she-ha-hipo menagev et ha-yeled. Mi amar et-ze?
The boy said that the hippo is drying the boy. Who said that?

To test the Go Lighter principle 15 items were composed. Each picture included 3 characters, which were introduced using full noun phrases. All items included two sentences. The first sentence in each item included one noun phrase and a verb, and the second sentence included two noun phrases and a verb. One of the two noun phrases in the second sentence repeated the noun phrase of the first sentence (examples 15 and 16); 7 of the sentences were coordinated with ‘‘and‘‘, and 8 included an adjunct introduced by ‘‘because‘‘. Thus, in both types of sentences, the two noun phrases were not in a c-command relation (see Section 4.1).

(15)



Ha-isha xiyxa biglal she-ha-isha sirka et ha-yalda. Mi xiyxa?
The woman smiled because that the woman combed the girl. Who smiled?

(16)

Ha-yeled xiyex biglal she-ha-melex sirek et ha-yeled. Mi xiyex?
The boy smiled because that the king combed the boy. Who smiled?

Under Go Lighter, coreference of the two identical nominal expressions would be proscribed; hence the correct answer to the Wh-question consisted here in pointing to the woman, or the boy, not involved in the other action.

The filler items included 6 pictures with three characters and a Which PP object question was asked (see example 17).

(17)

Al eizo safta ha-yalda yoshevet?
On which grandmother does the girl sit?

In each sentence, the two DPs were of the same gender. The items were presented in randomized order, and were read by the experimenter while the pictures were presented in front of the participant.

Table 5
The performance (percentage correct) of the aTOMic individuals (and healthy controls) in the sentence-picture matching test of Binding Principles A, B, & C and the GL (Go Lighter) Principle.

	Aharon	Shalom	Yoni	Tuvia	Samson	aTOMic Average	Control
Fillers	100	100	100	100	100	100	100
Principle A	93	100	93	73	100	92	100
Principle B	100	100	93	93	100	97	100
Principle C	87	100	73	67	67	79	99
GL Principle	60	60	64	21	14	44	97

5.3. Results

As summarized in Table 5, each of the 5 participants performed better on the principle C items than on the Go Lighter items, a difference that was significant at the group level, $t(4) = 4.52$, $p = .005$, $d = 4.52$. This difference was also significant for two of the participants.[7]

All five participants showed good purely syntactic abilities: All of them performed well on principles A and B (not more than one error, except for Tuvia, who made 4 errors on the principle A items), and they were also all flawless on the PP object *which* questions filler items.

These results indicate that TOM impairment affects not only preference and judgment but also the interpretation of sentences: if the Go Lighter principle is not applied to sentences that the person with aTOMia hears, he might pick the incorrect individual as the referent of a repeating expression, when principle C is not there to exclude this option.

6. Discussion

In this study, we used the performance of twenty individuals whose syntax is intact but whose TOM abilities are impaired to explore the riddle of repeating referential expressions and what rules them out. We suggested a disentangling approach, according to which the repetition of referential expressions is guided by two principles – the syntactic principle C, which rules out the repetition of a referential expression c-commanded by another instance of the same expression, and a discourse principle, Go Lighter, which, given shared knowledge favors the use of a pronoun instead of a full DP.

The performance of the individuals with TOM impairment supported this disentangling approach to repeating referring expressions. These patients failed on various TOM tests but showed very good performance in the sentences that tested principles A and B, the syntactic principles that determine the distribution and interpretation of pronouns and reflexives.

This dissociation was reflected in their performance in judging sentences with repeated R-expressions in the second experiment. Even though this experiment included relatively few sentences, the results were clear, consistent across patients, and statistically significant: Whereas the aTOMic participants could easily rule out sentences in which principle C excludes repetition, they failed to detect the deviance of sentences with repeated noun phrases for which they could only rely on the Go Lighter principle. Notice that the computation of the relevant configurational conditions for principle C may not be immune from pathology in general. For instance, Sambin et al. (2012) give evidence that patients with Huntington's disease have problems in properly computing principle C, in sharp contrast to what we found in the aTOMic patients of our study.[8]

The results of Experiments 1 and 2 were corroborated by those of Experiment 3, which tested the computation of the binding principles and Go Lighter through their consequences for sentence comprehension. The third experiment specifically tested principle C not only in configurations with repetition of full noun phrases in a c-command relation, but also in configurations in which the c-commanding nominal expression was a pronoun. These paradigmatic cases of application of principle C, crucially relying on the structural relation of c-command, were computed properly by the aTOMic patients; this confirms their intact syntactic abilities, consistently shown by their good scores in the principles A and B tests. Our disentangling approach was supported by the comparison with their scores in the comprehension of the Go

[7] The items on which the participants in the principle C condition erred were almost only of the type "The aunt *said* that the aunt combed the girl. Who said?" (4 out of the 5 errors that Tuvia and Samson made, and 3 of Yoni's 4 errors). The reason for this failure may have been their aTOMia, which made it difficult for them to considering information from the point of view of others. In other principle C items their performance was better (90% – they erred in only 1 out of the remaining 10 C items). It is worth noting that when we ran the same test with a group of 11 school-aged children on the autistic spectrum, they made errors on the same *saying* items and performed well on the other C items.

[8] Sambin et al.'s study did not include stimuli with repeated R-expressions in the non-c-command condition, so it cannot be claimed, on the basis of the evidence so far available, that Huntington and aTOMic patients manifest a double dissociation in this respect.

Lighter items in which they performed poorly, confirming the results of Experiment 2 through a completely different technique. Hence, the disentangling approach is globally supported by a robust set of results.

These results give clear support to the view that there is a sharp division of labor in determining the distribution and interpretation of referential dependencies between configurational principles based on c-command such as A, B, and C, and a conversational principle such as the Go Lighter principle. The division of labor is especially clear between the syntactic configurational principle C, and a conversational principle presupposing shared knowledge, hence theory of mind considerations. The two different components are clearly disentangled by the performance of individuals with TOM impairment, who have consistently shown no special difficulty in computing referential dependencies regulated by the syntactic principle C, much as in the computation of principles A and B. In the minimal comparison between principle C and Go Lighter, they have shown a selective impairment only with respect to the conversational principle.

These results also indicate that principle C cannot be reduced to general cognitive factors. Some researchers in pragmatics suggested that grammatical knowledge can be subsumed under processing efficiency considerations. In psycholinguists, researchers such as Harris and Bates (2002) advocated a similar view, suggesting that syntax can be reduced to cognitive functions and is not an independent source of principles that regulate on-line processing. For example, they stated that ''our position is that c-command may correlate with grammaticality intuitions . . . but this does not require that children (or adults) have knowledge of the c-command principle. . . On this view, c-command's descriptive success is a by-product of the functional properties of sentential structure'' (p. 239). The current research shows that whereas discourse principles like Go Lighter may in fact stem from cognitive efficiency considerations, syntactic principles that involve C-command are still separately computed. The finding that individuals who could not use discourse considerations could still use the syntactic principle C proves that the syntactic principle cannot be reduced to the general cognitive ones.

A different type of implication of these results is that it turns the spotlight to a population that usually does not receive speech therapy. Although the formal syntactic component of the linguistic ability of individuals with TOM impairment is unaffected by their brain damage, their overall language-related performance appears to be affected in specific respects. This suggests the possibility of a treatment tailored to the specific characteristics of the observed impairment.

Appendix A

The aTOMia battery (see Balaban et al., in press, for a detailed description of each of the tasks) was comprised of 8 different categories of TOM tasks. Each of the 8 categories represented a different aspect of the TOM ability (first order false belief, second order false belief, knowledge gaps, instruction, faux pas, surprise, empathy, and understanding of cartoons). Each category included two different items. All items were presented to the participants in writing and were read aloud by the experimenter. The participants were encouraged to follow the written text while the experimenter read the items.

For example, in the ***Second-order false belief category*** one of the items was a story about a mother who planned to give her son a puppy as a surprise birthday gift (partly based on Sullivan et al., 1994). To keep it a surprise she told her son he will get a wonderful game and then left for work. While the mother was out, the son discovered the puppy and understood that it was his real birthday gift. At this point we asked the participant two questions: a fact question: *Where did the mother go?* (work) and a comprehension question: *Does the mother know her son found the puppy?* (no). Next, we continued the story and introduced a third character, a friend of the son. The son told his friend that he will be getting a puppy for his birthday and the friend asked to come over and play with it before the party. At this stage, each of the three characters held different information regarding the others' thoughts and knowledge about the birthday gift. The mother thought that her son did not know what the real gift was; the son's friend didn't know that the mother was hiding the real gift and the birthday boy knew what the real gift was and what his mother said the gift would be. Next we presented a yes/no second order false belief question (A) *Will the boy agree to have his friend over to play with the puppy before the party?* and asked the participant to explain their answer. The expected answer was that the son would not agree because he knew his mother did not know the puppy was discovered.

We used this type of question in order to evaluate the participants' ability to reason about mental states of others when they are not explicitly asked about mental states and knowledge. The fact question was used to ensure understanding of the story. If a participant erred in these questions the story or the relevant details were clarified. The yes/no TOM questions were coded as either correct or incorrect (1/0), and the justifications were coded as appropriate or inappropriate (0/1). In coding the justifications we only considered the participants' reference to shared knowledge or knowledge gaps between the protagonists (and did not refer to their grammaticality). An item was considered correct only if the participant gave a correct yes/no answer and an appropriate justification.

Appendix B

The ***relative clause comprehension*** task was comprised of 60 semantically reversible sentences: 20 simple SVO sentences (e.g., 'The boy is soaping the penguin'), 20 subject relative clauses (e.g., 'Show me the boy that is soaping the penguin'), and 20 object relative clauses (e.g., 'Show me the penguin that the boy is soaping'). The sentences were presented in a random order. Because Hebrew verbs agree with the subject in gender, number and person, all sentences included characters of the same gender and number, in order to preclude an agreement cue on the verb. While the participant heard a sentence, she was shown a page with two pictures (e.g., Fig. B1) and was asked to point to the one that matched the sentence she heard. In one picture the roles matched the sentence; in the other the roles were reversed. There were 20 picture pairs, each was shown three times, each time with a sentence of a different type.

The Comprehension of Wh-questions task included forty questions: 20 *which subject* questions (e.g., Which girl caresses the mother?) and 20 *which object* questions (e.g., Which girl does the mother caress?). The experimenter asked a question while the participant was looking at a picture. The participants were requested to point to the figure in the picture that properly answered the question. Each picture included three figures: two of the same type which differed in at least one feature (e.g., a blond and a dark-haired girl) and a third figure of a different kind (e.g., the mother). In each picture, the first figure was performing an action on the second, and the second figure was performing the same action on the third figure, which was of the same type as the first one (Fig. B2). There were twenty pictures of triads of figures. Each picture was presented twice, each time with a different type of question.

Fig. B1. A picture pair presented in the relative clause-picture matching task.

Fig. B2. An example for a picture used in the WH-question comprehension task.

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