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Athlete or athletic? Limited differential brain activation in person descriptions using nouns or adjectives ☆

Laurens Van der Cruyssen [a,b,*], Ceylan Özdem [a], Tessa Haesevoets [b], Marie Vandekerckhove [a], Frank Van Overwalle [a,*]

[a] Vrije Universiteit Brussel, Belgium
[b] Ghent University, Belgium

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ABSTRACT

Do differences between the syntactic categories of nouns and adjectives for describing persons translate into different patterns of brain activation? In this fMRI study, we compared reading person and object descriptions denoted by nouns or adjectives. Previous behavioral studies found that nouns, describing the more abstract construct of social categories, compared to adjectives, describing the more concrete construct of personality traits, have an impact on the inferences made about a person. Additionally, previous neuroimaging findings suggest that abstract constructs recruit a different pattern of brain activation, compared to more concrete constructs. Participants read sentences describing a protagonist by means of a noun or an adjective, as well as sentences describing objects through a noun or an adjective. The results revealed that reading nouns as opposed to adjectives showed increased activation in the left lingual gyrus for persons, and additionally in the right lingual gyrus for objects. The results indicate that there are limited differences in the processing of nouns and adjectives when describing persons.

1. Introduction

Do you prefer being described as an *athlete* or *athletic*, as an *entrepreneur* or *entrepreneurial*, as an *enthusiast* or *enthusiastic*? Not only the content of the language we use to describe and represent others appears to be important, also the linguistic characteristics of that description appear to be of great importance. In his highly influential work on prejudice, Allport singled out nouns as the syntactic category which plays a key role in reflection, recall, identification and action related to generalizations about our social environment (Allport, 1979). This linguistic form is typically used when describing social categories and stereotypes. Social categories refer to groups of people who are denominated by a socially shared label and are characterized by specific features like occupations and belief systems (Andersen & Klatzky, 1987), while stereotypes refer to the accumulated knowledge and beliefs observes have about social categories (McGarty, 2002; Tajfel, 1981). Social categories, like *African Americans*, as well as stereotypes about them (e.g. *athletic*) allow us to cognitively, affectively and behaviorally organize our social environment, as well as predict possible behavior of its protagonists (Allport, 1979; Fisk & Neuberg, 1990).

When forming an impression of another person, we often categorize them by means of these social categories using nouns (e.g., athletes), rather than individuating them by referring to their personality traits using adjectives (e.g., athletic), which denote essential qualities of people, often inferred from specific behavior (Andersen & Klatzky, 1987; Bodenhausen, Macrae, & Sherman, 1999a; Bodenhausen, Macrae, & Sherman, 1999b). Even though both social categories and traits have received ample attention in research on impression formation, the impact of nouns and adjectives as syntactic categories for representing groups versus individuals has been lacking in social neuroscientific research. The current study attempts to answer the question whether the differential use and impact of nouns and adjectives in person perception is reflected in distinct neural correlates in the brain.

1.1. Nouns vs. adjectives in person perception

Through the representation of social categories, nouns are related to group membership, compared to the more individual oriented traits. Social categories represent a more complex cluster of information than traits do. Despite their complexity, a noun describing a social category appears to be more imaginable and

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* Corresponding authors at: Department of Psychology, Vrije Universiteit Brussel, Pleinlaan 2, B - 1050 Brussel, Belgium.

E-mail addresses: Laurens.Van.der.Cruyssen@vub.ac.be (L. Van der Cruyssen), Frank.VanOverwalle@vub.ac.be (F. Van Overwalle).

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Table 1
Contrasts for syntactical type and person/object.

Comparison and anatomical area	x	y	z	Voxels	max F/T	
Noun person > Adjective person						
Left lingual gyrus	−10	−78	0	55	5.97	**
Adjective person > Noun person						
		–				
Noun object > Adjective object						
Left lingual gyrus	−12	−78	−2	148	6.65	***
	−8	−82	4		6.54	***
Right lingual gyrus	14	−78	2	35	5.81	**
Adjective object > Noun object						
		–				
Conjunction of each of the four conditions > baseline						
Left lingual gyrus	−34	−82	−4	302	8.61	***
	−22	−94	−6		6.69	***
Right lingual gyrus	22	−88	−2	138	6.17	***
	34	−86	−4		5.58	**
Noun > baseline						
Left inferior frontal gyrus (pars Triangularis)	−46	28	18	30	5.27	*
	−46	18	24		5.04	*
Left inferior frontal gyrus (pars Opercularis)	−38	8	24	82	5.64	**
	−48	4	54	313	5.33	**
Left postcentral gyrus	−52	−8	46		6.68	***
Left SMA	−4	0	60	137	6.72	***
Left middle temporal gyrus	−62	−36	2	11	5.17	*
Left inferior parietal lobule	−24	−66	44	72	5.64	**
Left superior parietal lobule	−28	−72	52	72	5.15	*
Left inferior occipital gyrus	−38	−74	−6	1110	∞	***
Left middle occipital gyrus	−36	−82	−4		12.37	***
Left inferior occipital gyrus	−22	−94	−6		∞	***
Right inferior occipital gyrus	40	−82	−8	439	5.94	***
	34	−86	−4		6.83	***
Right lingual gyrus	24	−90	−2		7.61	***
Adjective > baseline						
Left inferior frontal gyrus (pars Triangularis)	−46	28	18	16	5.29	*
	−44	10	28	61	5.15	*
Left inferior frontal gyrus (pars Opercularis)	−38	6	24		5.46	**
Left SMA	−4	0	60	56	5.73	**
Left postcentral gyrus	−52	−8	48	58	5.55	**
Left inferior parietal lobule	−24	−66	44	13	5.30	**
Left inferior occipital gyrus	−38	−74	−6	1180	∞	***
Left middle occipital gyrus	−36	−82	−4		12.58	***
Left inferior occipital gyrus	−22	−94	−6		∞	***
Right inferior occipital gyrus	40	−76	−10	443	5.49	**
	34	−86	−4		7.11	***
Right lingual gyrus	24	−90	−2		∞	***
Person > object						
		–				
Object > person						
Left inferior frontal gyrus (pars Orbitalis)	−44	40	−12	62	6.68	***
	−50	34	−14		5.46	*

Note: x, y, and z = Montreal Neurological Institute coordinates of the peak values in the left–right, posterior–anterior, and inferior–superior axes respectively; t = t-score of the peak values. Whole brain analysis with $p < 0.05$ (FWE-corrected) and cluster extent >10 voxels; listed are clusters and peak coordinates that are significant at $p < 0.05$, FWE-corrected.
[*] $p < 0.05$.
[**] $p < 0.01$.
[***] $p < 0.001$ (FWE-corrected).

idiosyncratic than an adjective describing a personality trait, making nouns more salient in our memory (Andersen, Klatzky, & Murray, 1990). Social categories and traits also differ with regard to their level of abstraction, with social categories being more multileveled and complex concepts that involves a higher level of abstractness, also termed *level of construal*, while traits only convey the concrete, less abstract behavior they summarize (Andersen et al., 1990; Macrae, Milne, & Bodenhausen, 1994; Trope & Liberman, 2010). Level of abstractness plays an important role in the Linguistic Category Model (LCM). This model divides our language about interpersonal communication into five different categories of interpersonal terms, organized by increasing level of abstraction moving away from concrete event descriptions towards abstract stable characteristics of an individual (see Semin, 2009, for review). The first four levels of this model describe interpersonal actions through verbs, while the highest level of abstraction in this model is reserved for adjectives, yet nouns are not accounted for in this model (Semin, 2009).

Even though the distinction between nouns and adjectives has primarily received attention in the context of the social categories and the traits they represent, the linguistic difference itself has not completely been neglected in behavioral research. Recent findings suggest that nouns have more inductive potential compared to adjectives. Nouns describing social categories trigger more stereotypical inferences, inhibit counterstereotypical inferences, and allow stronger inferences about a target which are more persistent and less affected by situational constraints (Carnaghi et al., 2008). In contrast to nouns, adjectives do not form a universal word class as they do not appear in every language (Dixon, 1982).

1.2. Neuroscientific findings

Neuroimaging studies on social categories and personality traits have revealed the involvement of a network of brain regions related to mentalizing, that is, the perception of other person's behavior as driven by internal mental states like thoughts, emotions, beliefs, personality traits, and social categories (Cloutier, Gabrieli, O'Young, & Ambady, 2011; Ma et al., 2012; Mende-Siedlecki, Cai, & Todorov, 2012; Spreng, Mar, & Kim, 2009; Van Overwalle, 2009). The mentalizing network consists of various areas along the medial axis including the medial prefrontal cortex (mPFC), posterior cingulate cortex (PCC), and precuneus, as well as lateral areas including the temporo-parietal junction (TPJ), posterior superior temporal sulcus (pSTS), and anterior temporal lobe (aTL) (Van Overwalle, 2009; Van Overwalle & Baetens, 2009).

Previous studies have suggested that activation in this network may not be exclusively related to social reasoning, but might involve the construal level at which data is processed (Baetens, Ma, Steen, & Van Overwalle, 2013; Gilead, Liberman, & Maril, 2013; Grossman et al., 2002). Grossman et al. (2002) presented nouns varying in level of abstraction and participants indicated the pleasantness of these nouns. The authors found that abstract nouns showed more activation in the mPFC, TPJ and inferior frontal gyrus in the left hemisphere than concrete nouns (Grossman et al., 2002). More recently, Baetens et al. (2013) provided pictures of people displaying everyday behavior or of objects. In this study, participants had to generate a personality trait or object category to induce high construal reasoning, or they had to visually describe the pictures in order to induce low construal reasoning. The authors found that the mentalizing network, including the mPFC, TPJ, precuneus and PCC, was engaged during reasoning at a high construal level with substantial overlap between persons and objects (Baetens et al., 2013). In a study applying a similar logic, Gilead et al. (2013) asked participants to indicate 'why' a person performed a certain activity to induce high construal reasoning, while participants had to explain 'how' a certain activity is performed to induce low construal reasoning. They compared this to reasoning about objects at different construal levels by asking them to generate superordinate categories (high construal) or subordinate exemplars (low construal) for the same objects. The results only partly replicated the previous studies (Baetens et al.,

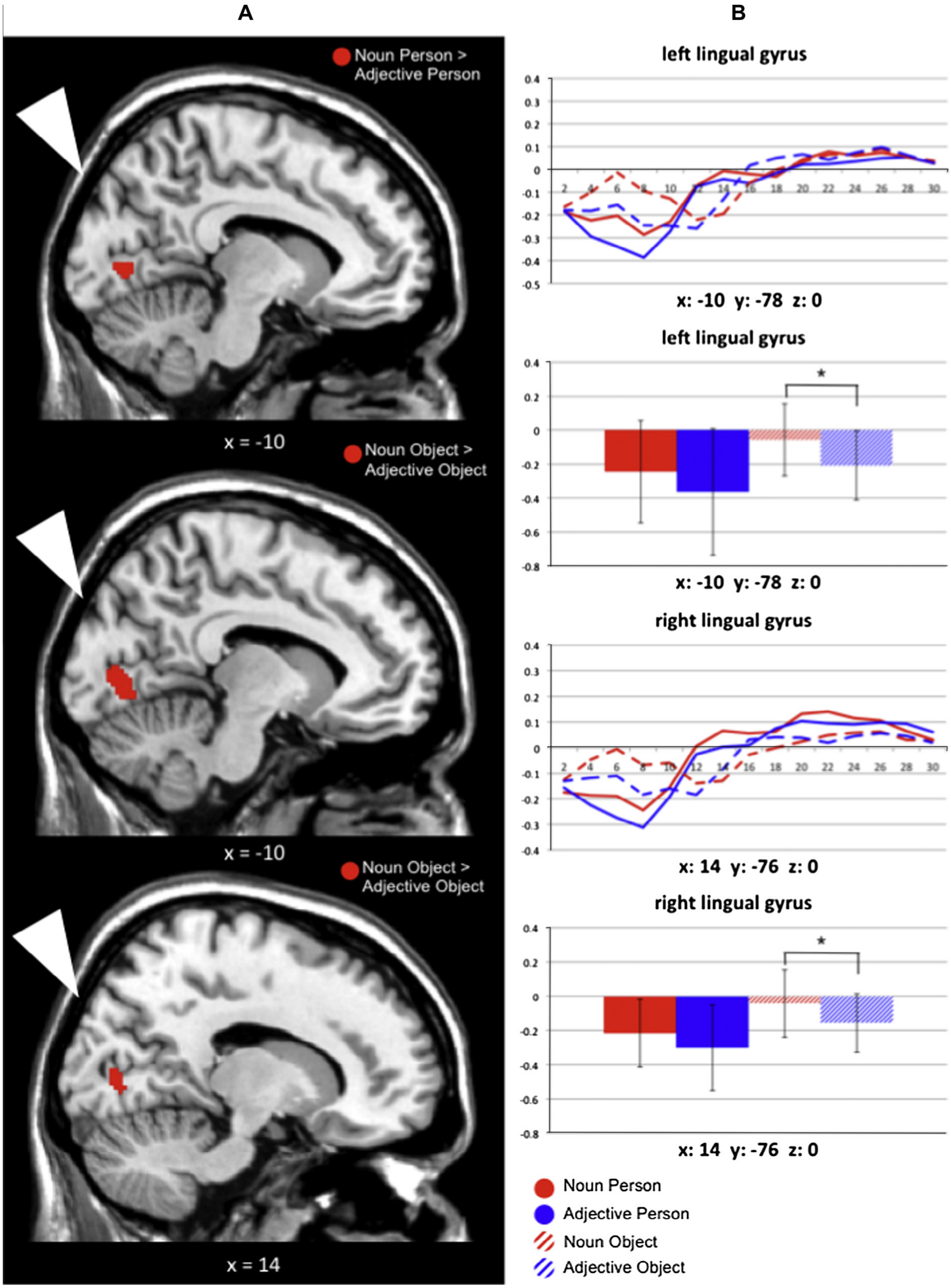

Fig. 1. Brain activation related to the processing of Syntactic Category. (A) Whole-brain contrasts thresholded at $p < 0.05$ (FWE-corrected) with a minimum cluster extent of 10 voxels. (B) Finite Impulse Response (FIR) time course in percentage signal change per 2 s from 2 s to 30 s for the regions of interest indicated by the arrows in A.

2013; Grossman et al., 2002), and revealed that high construal reasoning involved activation in the occipital regions related to visual perception, while low construal reasoning engaged fronto-parietal regions (including the left inferior frontal gyrus and TPJ) related to action monitoring (Gilead et al., 2013; Van Overwalle & Baetens, 2009). The authors also found activation in the mentalizing net-

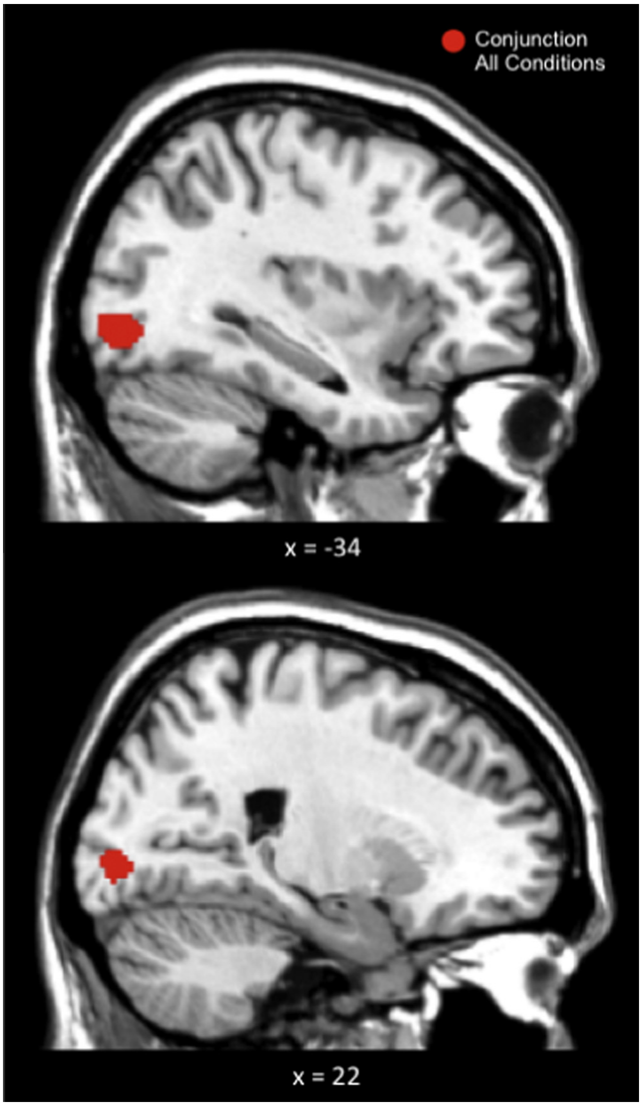

Fig. 2. Brain activation related to the conjunction of all conditions compared to an implicit baseline. Whole-brain contrasts thresholded at $p < 0.05$ (FWE-corrected) with a minimum cluster extent of 10 voxels.

work during high construal reasoning about a person, but only at a lower uncorrected threshold (Gilead et al., 2013).

Neurolinguistic research has paid little attention to the distinction between nouns and adjectives, and has primarily studied differences between action-related concrete verbs and entity describing abstract nouns as both are universal word classes and have each been related to specific neuropsychological deficits (Bedny, Caramazza, Grossman, Pascual-Leone, & Saxe, 2008; Dixon, 1982; Finocchiaro, Basso, Giovenzana, & Caramazza, 2010; Li, Jin, & Tan, 2004; Peelen, Romagno, & Caramazza, 2012; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011). Several studies have found increased activation for reading verbs compared to nouns, but report little to no significant activation in the reverse comparison (Bedny et al., 2008; Davis, Meunier, & Marslen-Wilson, 2004; Peelen et al., 2012; Perani et al., 1999; Willms et al., 2011). This increased activation may be due to higher processing requirements during verb reading in comparison with nouns, perhaps due to the greater variation in verb inflections than nouns. And indeed, one study in which participants had to inflect verbs as well as nouns rather than only reading them, found the opposite results with nouns showing more activation compared to verbs (Sahin, Pinker, & Halgren, 2006). In line with the findings of this study, recent reviews suggest that not syntactic category, but semantic content and the experimental task may explain the differences in recruitment of specific brain regions found in previous studies (Mätzig, Druks, Masterson, & Vigliocco, 2009; Vigliocco et al., 2011). Additionally, findings from a lesion study by Piras and Marangolo (2007) suggest verb and noun processing might not require segregated neural modules, but rely on a more continuous fronto-temporal network.

To our knowledge, a direct comparison between the neural patterns of nouns and adjectives in an identical context of social understanding is lacking. Exploring this comparison would advance our understanding of syntactical categories in social inference, provide the neural correlates of basic noun versus verb categories in social perception and potentially extent the Linguistic Category Model (Semin, 2009). Perhaps it may also shed some light on the neural substrates of verbs and nouns in general.

1.3. The present research

In the present study, we explore in what way differences in syntactic category, in particular nouns and adjectives, reveal different patterns of activation during the processing of persons. During the main task of the experiment, we briefly presented a fictional person with an associated characteristic denoted by a noun (e.g., athlete) or an adjective (e.g., athletic). This was followed by a question to compare the fictional person to a well-known person (this person possessed a characteristic congruent to the fictional person in 50% of the presentations) to ensure that the participants would retrieve information related to the presented characteristic. To control for brain activation due to linguistic differences between nouns and adjectives and unrelated to person perception, we added a control task in which an object (e.g. "The tree is ...") was presented with an associated characteristic denoted by a noun (e.g., "a pine") or an adjective (e.g., "thin"). Participants were instructed to read this information carefully. Unlike the person impression task, this task was not followed by a question.

Based on previous findings, we expect that the processing of a noun for describing a person will reveal increased activation in regions of the mentalizing network related to the processing of abstract information, such as the mPFC, angular gyrus/temporo-parietal junction, (pre)cuneus, posterior cingulate gyrus, and cerebellum (Baetens et al., 2013; Gilead et al., 2013; Schurz, Radua, Aichhorn, Richlan, & Perner, 2014; Van Overwalle, 2009), compared to adjectives which we expect to show increased activation in regions related to the mirror-neuron network and the processing of concrete information, such as the inferior frontal gyrus/premotor cortex, lateral frontal gyrus, inferior parietal lobule, precuneus and middle temporal gyrus (Baetens et al., 2013; Gilead et al., 2013).

2. Method

2.1. Participants

Twenty six native Dutch-speaking undergraduate and graduate students from Ghent University and Vrije Universiteit Brussel (12 women, ages ranging between 18 and 28, mean age 22.75 years) participated in exchange for 10 euro. One participant was later excluded due to movement artifacts. All participants were right-handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). The participants had no abnormal neurological history and had normal or corrected-to-normal vision. Informed consent was obtained in a manner approved by the Medical Ethics Committee at the Hospital of University of Ghent (where the study

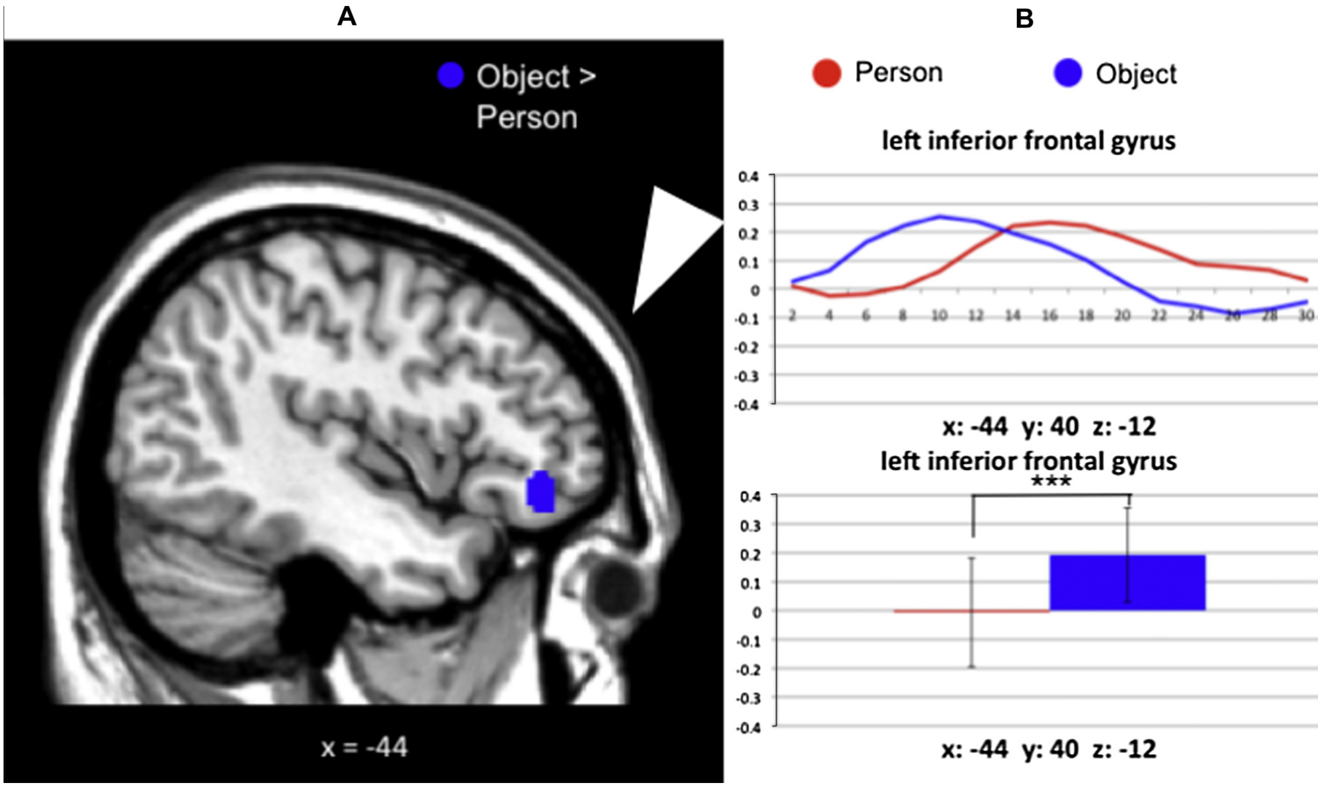

Fig. 3. Brain activation related to the processing of Target. (A) Whole-brain contrasts thresholded at $p < 0.05$ (FWE-corrected) with a minimum cluster extent of 10 voxels. (B) Finite Impulse Response time course in percentage signal change per 2 s from 2 s to 30 s for the region of interest indicated by the arrow in A.

Table 2
Contrasts between mean percentage signal change involving person or object conditions in time window 6–8 s for a priori ROIs.

A priori ROI	x	y	z	Mean PSC person	Mean PSC object	Contrast: Person vs. object	Contrast: Person vs. baseline	Contrast: Object vs. baseline
dmPFC	0	50	35	−0.006	0.103	*		***
vmPFC	0	50	5	−0.068	−0.024		*	
Left aTL	−45	5	−30	−0.013	0.007			
Right aTL	45	5	−30	−0.077	−0.034		***	
Left PMC	−40	5	40	0.031	0.158	***		***
Right PMC	40	5	40	−0.069	−0.039		***	*
Left aIPS	−40	−40	45	−0.031	0.069	**		***
Right aIPS	40	−40	45	−0.137	−0.033	***	***	
Left pSTS	−50	−55	10	−0.085	0.037	**	**	
Left TPJ	−50	−55	25	−0.018	0.098	**		**
Right pSTS	50	−55	10	−0.138	−0.074	*	***	***
Right TPJ	50	−55	25	−0.080	−0.075		***	**
Precuneus	0	−60	40	−0.057	−0.118			**

Note: x, y, and z = Montreal Neurological Institute coordinates of the peak values in the left–right, posterior–anterior, and inferior–superior axes respectively.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

was conducted) and of the Vrije Universiteit Brussel (of the principal investigator Frank Van Overwalle).

2.2. Procedure and stimulus material

The participants first received oral and written instructions about the upcoming experiment before entering the scanning-room. A list with stimulus words, which did not contain any personality characteristics (e.g., "athletics", from which we derived the stimulus noun "athlete" and the stimulus adjective "athletic" for the experiment) was presented to the participants. Participants were tested to verify that they knew the content of each word, and therefore also the content of the noun and adjective derived from that word. There were no significant differences between the nouns and adjectives with regard to word length, $t(114) = 1.90$, $p = 0.06$, amount of syllables, $t(99) = 0.86$, $p = 0.44$, and Log10 word-frequency, $t(118) = 0.78$, $p = 0.39$ as assessed through the use of the SUBTLEX-NL database (Keuleers, Brysbaert, & New, 2010).

During fMRI-scanning, the participants were presented with two tasks. In the main task of the experiment, a personality description of a protagonist was presented for a duration of 6 s, followed by a similarity judgment, which terminated upon the participant's reaction. Each protagonist received a 'star trek'-like name to

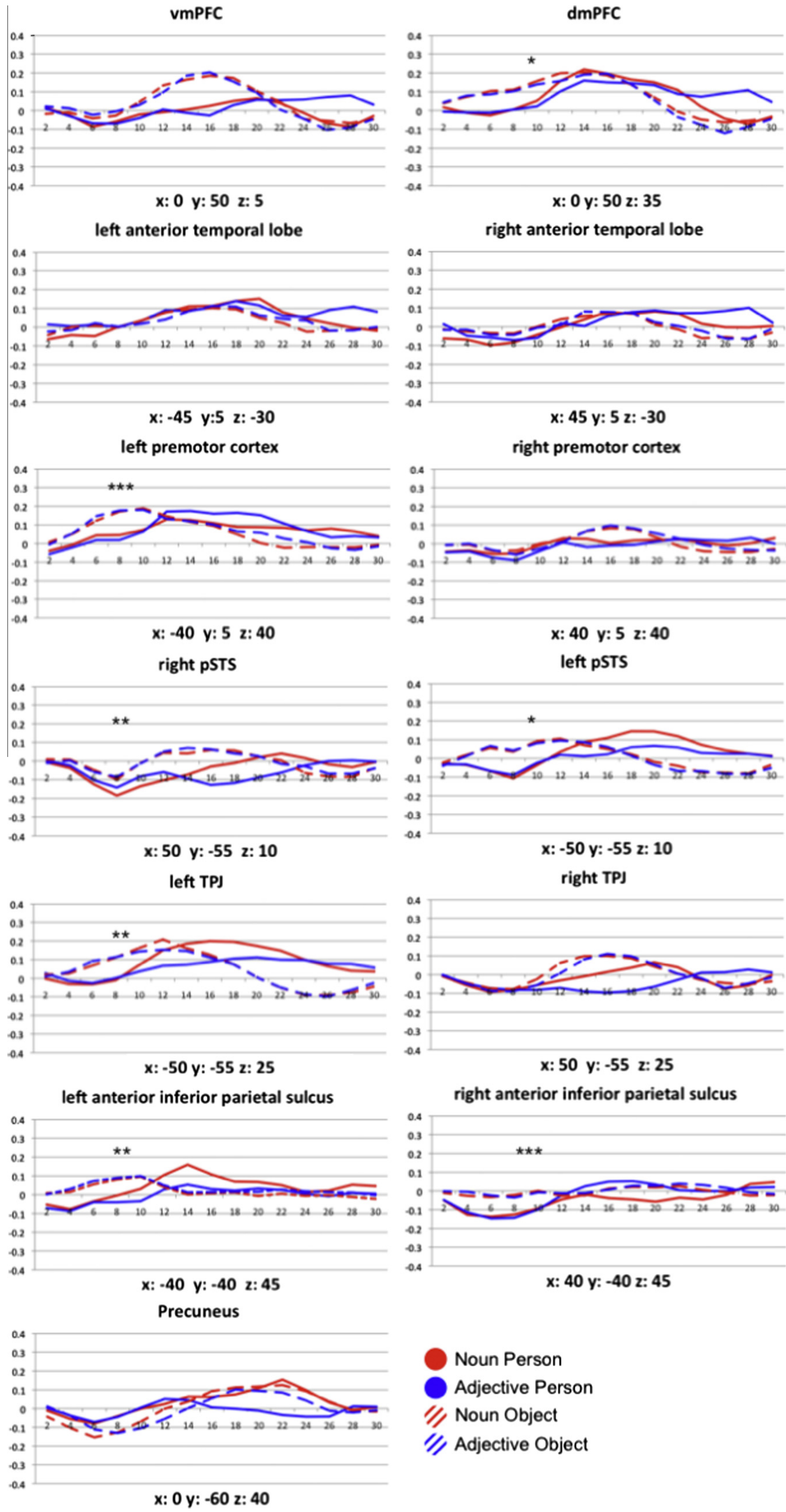

Fig. 4. Brain activation related to the processing of Syntactic Category. Finite Impulse Response time course in percentage signal change per 2 s from 2 s to 30 s a priori determined regions of interest (ROI's). The figures are organized anterior-posterior.

avoid association with a known person. The behavioral description consisted of either a noun (e.g., "Vortram is an athlete") or an adjective (e.g., "Vortram is athletic"). This was followed by a similarity judgment task, in which participants received the name of a famous person, with whom they had to compare the previously presented protagonist. In a pilot study, the list of famous people was pretested on 61 undergraduate students to ensure that these people are seen as having a specific personality trait (e.g., "Steve Jobs is innovative/ an innovator"), or not having this trait at all (e.g., "Paris Hilton is brutish/a brute"). Before scanning, each participant checked the list containing famous people to ensure they knew who these people were. During the second, control task of the experiment, participants were presented with object descriptions consisting of either nouns (e.g., "the tree fruit is an apple") or adjectives (e.g., "the tree fruit is green"), for a duration of 6 s. No similarity judgments were requested. After the experiment, the participants selected for each pair of nouns and adjectives which one contained more action-inductiveness, predictability of future behavior, and imageability. Following this task, participants were debriefed and thanked.

2.3. Imaging procedure

Images were collected with a Siemens Magnetom Trio TIM scanner system (Siemens Medical Systems, Erlangen, Germany) using a 32-channel radiofrequency head coil. Stimuli were projected onto a screen at the end of the magnet bore that participants viewed by way of a mirror mounted on the head coil. Stimulus presentation was controlled by E-Prime 2.0 (www.pstnet.com/eprime; Psychology Software Tools) running under Windows XP. Participants were placed head first and supine in the scanner bore. They were instructed not to move their heads to avoid motion artifacts. Foam cushions were placed within the head coil to minimize head movements. First, high-resolution anatomical images were acquired using a T1-weighted 3D MPRAGE sequence [TR = 2530 ms, TE = 2.58 ms, TI = 1100 ms, acquisition matrix = $256 \times 256 \times 176$, sagittal FOV = 220 mm, flip angle = 7, voxel size = $0.9 \times 0.86 \times 0.86$ mm^3 (resized to $1 \times 1 \times 1$ mm^3)]. Second, whole brain functional images were collected using a T2*-weighted gradient echo sequence, sensitive to BOLD contrast (TR = 2000 ms, TE = 35 ms, image matrix = 64×64, FOV = 224 mm, flip angle = 80°, slice thickness = 3.0 mm, distance factor = 17%, voxel size = $3.5 \times 3.5 \times 3.5$ mm^3, 30 axial slices).

2.4. Image processing

The fMRI data were preprocessed and analyzed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK). For each functional run, data were preprocessed to remove sources of noise and artifact. Functional data were corrected for differences in acquisition time between slices for each whole-brain volume, realigned within and across runs to correct for head movement. The functional data were then transformed into a standard anatomical space (2 mm isotropic voxels) based on the ICBM152 brain template (Montreal Neurological Institute), which approximates Talairach and Tournoux atlas space. Normalized data were then spatially smoothed (6 mm full-width at half-maximum, FWHM) using a Gaussian Kernel. Finally, the preprocessed data were examined, using the Artifact Detection Tool software package (ART; http://web.mit.edu/swg/art/art.pdf; http://www.nitrc.org/projects/artifact_detect/), for excessive motion artifacts and for correlations between motion and experimental design, and between global mean signal and experimental design. Outliers were identified in the temporal differences series by assessing between-scan differences (Z-threshold: 3.0 mm, scan to scan movement threshold: 0.5 mm; rotation threshold: 0.02 radians). These outliers were omitted in the analysis by including a single regressor for each outlier. No correlations between motion and experimental design or global signal and experimental design were identified. Six directions of motion parameters from the realignment step as well as outlier time points (defined by ART) were included as nuisance regressors. We used a default high-pass filter of 128 s and serial correlations were accounted for by the default auto-regressive AR(1) model.

2.5. Statistical analysis

The statistical analysis of the fMRI data involved first-level single participant analyses with a regressor for each condition time-locked at the presentation of the sentence, 6 movement artifact regressors, and a variable amount of artifact regressors determined by ART (Gabrieli Lab, 2009; Whitfield-Gabrieli, Mozes, & Castanon, MIT). We estimated a model containing 4 regressors related to the experimental manipulations, namely noun about person, adjective about person, noun about object and adjective about object, and 2 regressors of no interest, namely similarity judgment after noun, and similarity judgment after adjective.

After defining the conditions in SPM8 (Wellcome Department of Cognitive Neurology, London, UK), a reparametrization procedure (developed by Wager & Lindquist) was applied to estimate the latency, height and width of the hemodynamic response function. This semi-parametric procedure models the hemodynamic response function for the data at the onset of each trial for each voxel individually, to allow estimation of the amplitude for each condition within a time window of 4–10 s post stimulus-onset. The analysis returns Area Under the Curve (AUC) images that take into account the time to reach maximum amplitude post stimulus onset, and the duration of the hemodynamic response. AUC images were created for each condition at participant level and subsequently used at the group-level. Analyses of interest were performed at the group second-level on the parameter estimates (regressors) associated with each condition using a random-effects model and involving the reading task only.

The statistical analysis involved a 2×2 full factorial ANOVA testing for the effect of Syntactic Category (nouns vs. adjectives) and Target (person vs. object). Statistical comparisons between conditions were tested by conducting an analysis of variance (ANOVA) on the parameter estimates associated with each trial type. Comparisons of interest were tested with one sample t-tests. A voxel-based statistical threshold of $p \leqslant 0.05$ (FWE-corrected) was used for all comparisons with a minimum cluster extent of 10 voxels. To test the activation unique to each condition, we compared each condition to an implicit baseline. Subsequently, we ran a conjunction analysis to verify the shared activation common to the contrast of each condition against the baseline.

To verify the whole-brain analyses, post hoc regions of interest (ROIs) were analyzed by taking a sphere of 8 mm radius around the peaks revealed in the whole brain analysis. To verify the hypothesized activation in mentalizing regions for persons, a priori ROIs were analyzed which involved a sphere of 8 mm radius around the centers (in MRI coordinates) of the areas identified in the meta-analyses by Van Overwalle (2009) and Van Overwalle and Baetens (2009) for mentalizing: dmPFC (0 50 35), vmPFC (0 50 5), bilateral anterior Temporal Lobe (aTL; ±45 5 −30), bilateral TPJ (±50 −55 25), bilateral pSTS (±55 −55 10) and precuneus (0 −60 40), and action-understanding through additional mirror areas: anterior intraparietal sulcus (aIPS; ±40 −40 45), premotor cortex (PMC; 0 20 −45). We estimated a Finite Impulse Response (FIR) model of the hemodynamic response at the participant-level, and extracted the time course and the mean percentage signal change from each ROI using the MarsBar toolbox (http://marsbar.sourceforge.net). We calculated the average percentage signal change in a time window of 6–8 s following the presentation of the person or object description, and analyzed the differences using one sample t-tests. Finally, we explored each region's involvement in person and object conditions by testing the average percentage signal change against the mean across all conditions (including the error; also termed the 'session' mean).

3. Results

3.1. Behavioral results

We conducted t-tests to explore the preferred choice of Syntactic Category (nouns vs. adjectives) in terms of action-inductiveness, predictability of future behavior and imageability. Adjectives were found to be significantly more action inducing ($M = 37.04$, $SD = 16.33$) than nouns ($M = 16.84$, $SD = 16.29$; $t(48) = 4.38$, $p < 0.001$), as well as significantly more imaginable (adjectives $M = 35.4$, $SD = 11.77$) than nouns ($M = 17.6$, $SD = 11.77$; $t(48) = -5.35$, $p < 0.001$). With respect to predictability of future behavior, nouns ($M = 22.6$, $SD = 18.16$) and adjectives ($M = 31.32$, $SD = 18.21$) did not differ significantly from each other, $t(48) = -1.70$, $p = 0.096$.

3.2. Imaging results

We conducted a whole-brain analysis in which we computed contrasts between nouns and adjectives separately for persons and objects (Table 1 & Fig. 1). Contrary to our expectations, nouns revealed more activation than adjectives in the left lingual gyrus for both persons and objects, and additionally in the right lingual gyrus for objects. Also contrary to our expectations, adjectives did not show increased activation compared to nouns. For informative purposes, we also computed contrasts between person and object conditions (Table 1). These conditions were not counterbalanced and must therefore be interpreted with caution. The results revealed increased activation in the left prefrontal cortex for objects compared to persons, while the reverse contrast was non-significant.

To identify the neural correlates of each syntactic category, we compared the activation against an implicit baseline (i.e. activation not included in the model; Table 1). The results revealed significant activation in the left inferior frontal gyrus, left SMA, left inferior parietal lobule, and bilateral inferior occipital gyrus for both nouns and adjectives, while nouns showed additional clusters in the left inferior frontal gyrus and left middle temporal gyrus. A conjunction analysis over all category conditions (each against the baseline; Table 1 & Fig. 2) revealed that only activation in the bilateral lingual gyrus was shared across nouns and adjectives ($p < 0.05$; FWE-corrected).

Second, to verify the activations revealed by the whole-brain analysis, we performed a Region of Interest (ROI) analysis on an 8 mm sphere surrounding the peak voxel in the activated clusters, and extracted the time course and the percentage signal change in each ROI. We then conducted t-tests on the percentage signal change. The results confirmed the whole-brain analysis on Syntactic Category, in that there was higher activation in the 6–8 s time window for nouns compared to adjectives in the bilateral lingual gyrus for objects, but not for persons (Fig. 1). The result in the 6–8 s time window also confirmed the whole-brain analysis of Target, in that there was increased activation in the left prefrontal cortex for objects compared to persons (Fig. 3).

Third, we performed similar ROI analyses on a priori defined regions related to the processing of social information, including regions from the action-related (i.e., verbs) mirror network as well as from the social-related (i.e., adjectives and nouns) mentalizing network (see method section). The results revealed significant differences in activation between persons and objects in the dmPFC, left PMC, bilateral pSTS, left TPJ and bilateral aIPS (Table 2 & Fig. 4). To explore whether these differences were driven by increased or decreased activation compared to baseline, we compared the percentage signal change for person and object against baseline (see method). The results showed significant deactivation for persons in the vmPFC, right aTL, right PMC, bilateral pSTS, right TPJ and right aIPS. For objects, the results revealed significant activation in the dmPFC, left PMC, left aIPS, and left TPJ, while showing significant deactivation in the right PMC, right pSTS, right TPJ and precuneus.

4. Discussion

The present study explored whether the processing of nouns and adjectives rely on different neural substrates, and whether neural activity is similar for social (person) or non-social (object) targets described by a noun or adjective. We reasoned that because nouns represent the more abstract construct of social categories, they would reveal more activation in the mentalizing network previously linked to abstract reasoning. Conversely, we suggested that because adjectives describe individualized personality traits, they would reveal more activation in regions previously linked to concrete reasoning. Contrary to our predictions, the results revealed that nouns only showed increased activation in the bilateral occipital region, and did not activate the mentalizing network more than adjectives. This finding appears to replicate that of Gilead et al. (2013) who observed increased activation in the occipital cortex only during the abstract reasoning. The authors attributed this to the increased heterogeneity of abstract categories preventing the built-up of activation in the same areas in comparison to concrete exemplars. Conversely, adjectives did not show any increased activation compared to nouns. Moreover, when comparing the activation of each syntactic category to baseline, both revealed activations in similar regions with only minor differences.

The present findings provide support for the claim that nouns and adjectives are likely not processed in different brain regions, but that differences between syntactic categories are related to their semantic content (Vigliocco et al., 2011). Thus, reading that someone was an 'athlete' or 'athletic' revealed no substantial difference, at least at the neural processing level. Given that nouns and adjectives seem not to differentiate in a person description, it is unlikely that *by themselves* social nouns solely refer to social categories or that social adjectives only refer to personality traits as we suggested, especially when the descriptions are so similar in semantic content. Although both may have their differences, they tend to share a similar function, namely providing information that allows us to predict future behavior of others, as well as integrate and coordinate our own cognitions, affect and behavior (Bodenhausen et al., 1999a, 1999b; Fiske, Lin, & Neuberg, 1999). Indeed, in a previous study by our lab, protagonists were described not only by social categories or personality traits that differed more strongly in semantic content (e.g., kindergarten teacher and friendly), but also by their distinct behaviors that were either consistent or inconsistent with these social descriptions and thus required a deeper processing effort (Van der Cruyssen, Heleven, Ma, Vandekerckhove, & Van Overwalle, 2015). Under these circumstances we found increased activation of the mentalizing system when protagonists were identified by a social category compared to a personality trait. This finding was interpreted as indicating that social categories induced more abstract reasoning compared to more concrete personality traits. Presumably, the behavioral descriptions in this earlier study, made these social identities more salient and vivid, rendering the social category versus trait identification more informative and diagnostic, leading to significant neural differences.

Interestingly, the results did not replicate a difference between persons and objects in the mentalizing network found in a previous study by Contreras, Banaji, and Mitchell (2012). This discrepancy in findings is likely to be related to a difference in the tasks. The current experiment did not require participants to make an explicit judgment at the time of reading, allowing us to separate the retrieval phase of the semantically stored information from the judgment phase.

Our behavioral findings reveal that adjectives are perceived as more action inducing and more imaginable than nouns, while they do not differ in behavior predictability. These results do not correspond to a previous behavioral study that found that nouns about a person allow stronger inferences about a target which are more persistent (Carnaghi et al., 2008). Our finding that nouns are less imaginable than adjectives and at the same time lead to increased occipital activation seem to correspond to Bedny and Thompson-Schill (2006) who found that a decrease in imageability of concepts was related to increased activation in the bilateral occipital lobe. Although these authors related this finding to increases in word-length, this explanation is of no relevance in the present study as it showed no significant differences in word-length between nouns and adjectives.

The current study also contains several possible limitations. Sentences in the object condition were not followed by a similarity judgment task, which may raise the question whether the comparison between person and object conditions might be confounded by this difference. We suggest that the impact of the similarity judgment task on the final results is limited at best given that the reading task and the similarity judgment task were properly jittered, which should allow accurate distinction between the estimated regressors (Dale, 1999). Furthermore, we don't want to underestimate the possible influence of the presentation order on these results. In this experiment, the object condition always appeared after the person condition, as the main focus of this study is with regard to the difference between nouns and adjectives in person descriptions, and the object condition was considered to be a control condition. Therefore, we wish to caution the reader that the differences between people and object could be due to an order effect, and that direct comparisons between the person and object condition are merely mentioned for informative purposes.

5. Conclusion

Our findings suggest that information very similar in semantic content, but presented either through nouns that describe social categories or adjectives that describe personality traits, is processed by similar brain regions. This similarity between these two syntactic categories appears to be similar for both persons and objects. The current study also suggests that involvement of the mentalizing system is limited when simply presenting information about social categories and personality traits, without providing behavioral descriptions.

Appendix A

Example stimulus material

	Noun	Adjective
Person	Kreslin is an animator	Kreslin is animating
	Glaba is an artist	Glaba is artistic
	Langu is a brute	Langu is brutish
	Brimi is a charmer	Brimi is charming
Object	The tree is a pine	The tree is thin
	The toy is a puppet	The toy is soft
	The fluid is a soda	The fluid is wet
	The cloth is a napkin	The cloth is velvet

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