Understanding approach and avoidance in verbal descriptions of everyday actions: An ERP study

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Abstract Understanding verbal descriptions of everyday actions could involve the neural representation of action direction (avoidance and approach) toward persons and things. We recorded the electrophysiological activity of participants while they were reading approach/avoidance action sentences that were directed toward a target: a thing/a person (i.e., “Petra accepted/rejected *Ramón* in her group”/ “Petra accepted/rejected the *receipt* of the bank”). We measured brain potentials time locked to the target word. In the case of things, we found a N400-like component with right frontal distribution modulated by approach/avoidance action. This component was more negative in avoidance than in approach sentences. In the case of persons, a later negative event-related potential (545–750 ms) with left frontal distribution was sensitive to verb direction, showing more negative amplitude for approach than avoidance actions. In addition, more negativity in approach-person sentences was associated with fear avoidance trait, whereas less negativity in avoidance-person sentences was associated with a greater approach trait. Our results support that verbal descriptions of approach/avoidance actions are encoded differently depending on whether the target is a thing or a person. Implications of these results for a social, emotional and motivational understanding of action language are discussed.

Keywords Approach/avoidance · Language · Action understanding · N400 · Frontal negativity

Approach/avoidance reactions toward stimuli are relevant for individual survival, as they facilitate seizing an opportunity (cued by positive stimuli) or escaping from a danger (cued by negative stimuli; Crawford & Cacioppo, 2002; Lang, Bradley, & Cuthbert, 1990; Zajonc, 1998). However, it is worth noting that we not only react toward stimuli but we also intentionally act toward them with a direction: approach (actions aimed at keeping the stimuli close) and avoidance (actions aimed at keeping the stimuli away or keeping distance from them; see Elliot, 2006). As far as we know, brain processing of approach/avoidance everyday actions has not been examined by previous research. Our study tries to fill this gap and focuses on directional actions in social and motivational contexts verbally described.

Everyday language frequently involves action direction by describing a protagonist’s attitude toward other people (see Marrero, Gámez, Díaz, Urrutia, & de Vega, 2015) or things. Attitudes contain an affective component (feelings either positive or negative) associated with a motivational component of approach-appetitive/avoidance-aversive (Cacioppo, Priester, & Berntson, 1993; Elliot, 2006; Lang et al., 1990; Zajonc, 1998; Zajonc & Markus, 1982). There is now a certain consensus in that action understanding, either observed or verbally described, is based on a process of simulation that requires a multimodal integration of motor, affective and cognitive components of action experience (Amoruso et al., 2013; Barsalou, 2008, 2009; Buccino et al. 2005; Gallese, 2003; Zwaan, 2004). Previous research has examined the role of motor (Buccino et al., 2005; Chersi, Thill, Ziemke, & Borghi, 2010; de Vega, Moreno, & Castillo, 2013; Glenberg & Kaschak, 2002; Moreno et al., 2015), affective (Havas,

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Glenberg, Gutowski, Lucarelli, & Davidson, 2010; Havas, Glenberg, & Rinck, 2007) and spatial (Black, Turner, & Bower, 1979; Bower & Rinck, 2001; de Vega, Beltrán, García-Marco, & Marrero, 2015) representations in action language understanding. However, the component of direction (approach/avoidance), a potentially relevant aspect of everyday action to be simulated for understanding, has received little attention. In particular, it has been shown that understanding verbally described everyday action activates approach and avoidance motor processes. In this regard, Claus and Bader (2008) showed that a judgment task of desiderative verbs was facilitated when response was made by an approach motor movement (pulling a joystick toward oneself) in contrast to avoidance movement (pushing it away). Likewise, Marrero et al. (2015) demonstrated that reading approach/avoidance social action verbs in interpersonal narratives interacted with approach/avoidance movements (stepping forward vs. backward, respectively) performed concurrently.

In this article, we focus on motivational language, and examine the encoding of direction (approach/avoidance) in verbal action sentences by means of ERPs. A large body of event-related potential (ERP) research has examined appetitive versus aversive stimuli processing, and approach/avoidance reaction with pictorial stimuli (Calvo, Marrero, & Beltrán, 2013; Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Gable & Poole, 2014; Luo, Feng, He, Wang, & Luo, 2010; Poole & Gable, 2014; Ruz, Madrid, & Tudela, 2013). However, in this study we record EEGs of participants while they are reading approach/avoidance past action sentences performed by persons (cued by proper names) toward things (cued by common names) or persons (proper names), and measure brain potentials from the onset of the target (person/thing). As our stimuli are verbal sentences, our brain should process them as a linguistic input. Processing linguistic sentences is a sequential process (Kluender & Kutas, 1993; Münte, Heinze, & Mangun, 1993; Münte et al., 2001); that is, subsequent words should be integrated with the previous context in the sentence semantically and grammatically to build up the meaning of the sentence. In this regard, it has been shown that semantic integration of a word with the previous sentence context produces a negative ERP peaking at 400 ms after stimulus onset and usually located in centroparietal sites (see Kutas & Federmeier, 2011, for a review). In general, content words in the context of sentences tend to elicit N400 modulated from features of words or other stimuli (Kutas & Federmeier, 2011). This so-called N400 component has been shown to be mainly sensitive to semantic incongruence and to other factors such as word frequency, word repetition, concreteness, expectancy, cloze-probability (Amoruso et al., 2013; Kutas & Federmeier, 2011), and even affective relevance (Van Berkum, 2010). It seems to be modulated not only bottom-up by low-level linguistic processes

but also top-down by high level more discursive processes. According to Kutas and Federmeier (2011), N400 latency and peak would represent the time point when a multimodal bottom-up and top-down association of brain information is merged into a common stream of semantic processing of incoming stimuli. Other ERP components have been associated with building a more elaborated mental representation or simulation of sentences, as a sustained negativity shift that would reflect ambiguity in establishing reference with respect to the situational model (see Van Berkum, Koornneef, Otten, & Nieuwland, 2007). Likewise, a frontal sustained negativity between 400 and 800 or 900 ms subsequent to N400 has been found in response to concrete words (in contrast to abstract words). This component has been differentiated from N400, and associated with word imagery processing (Huang, Lee, & Federmeier, 2010; Lee & Federmeier, 2008; West & Holcomb, 2000).

Relevant to our research, the process of integration of a given word in a previous context could differ depending on the linguistic category of the target word. Proper names (persons) and common names (things) are different categories, which could affect the integration of target words in sentences. In this regard, proper name encoding has been shown to involve deeper processing compared to common names (Dehaene, 1995; Müller & Kutas, 1996). Likewise, functional differences between common and proper names would be associated with separate neural mechanisms (see Proverbio, Lilli, Semenza, & Zani, 2001; Semenza, 2009). A deep processing of proper names has been explained in terms of their lack of semantic content (in contrast to common names; Müller & Kutas, 1996; Yasuda, Nakamura, & Beckman, 2000). In accordance with models of proper name processing, person name words (in contrast to common nouns) should be wholly processed in order to access a multimodal representation for identification of name bearers (its reference; Valentine, Moore, & Brédart, 1995; Wang, Zhu, Bastiansen, Hagoort, & Yang, 2013). On the other hand, a deep processing of proper names could represent evolutionary advantages by recognizing related from unrelated others in group situations (Müller & Kutas, 1996). Taking into account the difference between proper and common names encoding, and literature on ERPs in sentence understanding, we expect an N400 in the case of thing-target sentences, revealing semantic access to meaning as things are nouns with a semantic content. In contrast, in the case of person nouns, we might expect an ERP modulation subsequent to N400 wave reflecting more processing for building meaning.

ERP research on emotional language processing has mostly focused on isolated emotional words as stimuli. It has been found that word emotionality is associated with early ERP components (P1, N1, P2, EPN) and late ones. The N400 is associated with semantic processing of emotional words in contrast to neutral words, and a late positive complex (LPC)

reflects elaborative processing of emotional stimuli (Carretié et al., 2008; Herbert, Kissler, Junghöfer, Peyk, & Rockstroh, 2006; Kanske & Kotz, 2007; Kissler, Herbert, Winkler, & Junghofer, 2009). However, studies focusing on integration of affective stimuli in verbal contexts (i.e., sentences) have been relatively scarce.

Different patterns of ERPs have been found when instead of isolated stimuli, emotional words are presented in the context of sentences. More specifically, brain activity has been shown to be sensitive to the linguistic integration of words with emotional valence (negative vs. positive). Martín-Loeches et al. (2012) found that negative in contrast to positive words caused greater amplitudes of a left anterior negativity (LAN) ERP when participants were detecting syntactic anomalies, which involved a deeper processing of negativity, and a negative bias. Moreover, Hinojosa et al. (2014) have shown that negative valenced words caused shorter LAN amplitude than neutral words in detecting errors in a syntactic judgment task (gender agreement), which was interpreted in terms of processing priority for emotional words in contrast to neutral words. In addition, with a gender agreement task, Díaz-Lago, Fraga, and Acuña-Fariña (2015) showed a late positive (P600) ERP associated with word emotionality and grammaticality.

Likewise, it has been shown that brain activity is sensitive to semantic integration of emotional words (in contrast to neutral words) with previous verbal contexts. For example, Holt, Lynn, and Kuperberg (2009) found greater amplitude of N400 to emotional words (positive and negative vs. neutral) in reading sentences that described a previous similarly congruent context to the targets (see also Ding, Wang, & Yang, 2015). Other research goes deeper into the differential processing of positive versus negative emotional contents. Ding, Wang, and Yang (2016) have shown that negative verbs caused greater N400 amplitude than neutral verbs in a task where neutral nouns have to be integrated with a verb in a previous context. Likewise, Moreno and Vázquez (2011) have shown that N400 in response to an outcome was modulated by a valenced frame (positive/negative) in emotional sentences even when outcomes were highly expected. Moreno and Rivera (2013) found a post-N400 frontal positivity that was larger after unexpected positive outcomes, which was interpreted in terms of a greater difficulty to override lexically pessimistic outcome predictions. Other studies have found a smaller N400 for positive in contrast to negative words in integration of target words with sentence contexts (Martín-Loeches et al., 2012; Wang, Bastiaansen, Yang, & Hagoort, 2013), or in passive reading of isolated words (adjectives; Herbert, Junghofer, & Kissler, 2008). This supports a positive bias for the semantic integration of emotional words, probably because positive things are usually more expected than negative ones (Herbert et al., 2008). As can be seen, previous research has supported that emotionality

recruits resources which affect word processing, and that negative words recruit more processing for meaning than positive ones in the context of sentences.

A greater capacity of emotional words for recruiting additional resources to processing information would be monitored by our affective system, plausibly for adaptive reasons (Ding et al., 2015; Holt et al., 2009; Van Berkum, 2009). Our cognitive system seems to be shaped toward expecting the positive and a heightened sensitivity to the negative (Cacioppo & Gardner, 1999). In this context, we propose that action direction (approach and avoidance) like emotionality in words would constitute a semantic representation to be encoded in verbal descriptions of everyday actions, with priority for adaptive reasons: encoding direction of past actions toward environmental targets would be relevant to an adaptive regulation of individual behavior for subsequent interactions. Thus, we expect that ERP brain responses to actions toward things and persons will be modulated by the motivational direction in the sentences.

Moreover, in this study, we examine whether brain response to approach and avoidance direction differs between persons and things. On the one hand, it could be that direction is similarly encoded regarding persons and things. However, we consider that direction encoding could have different adaptive relevance to persons and to things. Encoding approach would be more relevant than avoidance in the case of person targets, as we are individuals of a cooperative species (see Cosmides, 1989): Not approaching others would involve a loss of social support with fatal consequences for individual survival. Encoding approach in past actions would discriminately regulate subsequent (positive) interactions toward persons who we like (as surely being trusted by us). In contrast, in the case of things, previous research has showed greater physiological, affective, cognitive, and behavioral activity in reaction to negative things in comparison with positive or neutral ones (Cacioppo, Larsen, Smith, & Berntson, 2004; Taylor, 1991; Vaish, Grossmann, & Woodward, 2008): Those who respond quickly to negative events increase their chances of survival (LeDoux, 1996). A quick response to removal of disliked things would depend on direction encoding of previous (recent) avoidance actions toward a target thing. If direction encoding differs between persons and things, greater amplitude of ERP indicating a more careful encoding of approach in the case of person targets, and of avoidance in thing targets would be expected.

A relevant characteristic of recent affective neuroscience research is to relate brain measures of basic processes to individual differences (Berkman & Lieberman, 2010; Carver & Harmon-Jones, 2009). Thus, we explore correlations of ERPs modulated by approach and avoidance sentences with approach and avoidance motivation traits. Significant correlations revealing the link between the approach/avoidance trait and ERP amplitudes associated with either approach or avoidance encoding

would support a motivational direction interpretation of ERP modulation. In order to measure approach/avoidance trait, we use the Carver and White scales that have been reported as being effective in several studies (Carver, 2006; Carver & White, 1994). The scales are a 20-item, four-point Likert-type with two scales, measuring individual differences on behavioral inhibition system (BIS) and on behavioral approach system (BAS; Corr, 2004; Gray & McNaughton, 2000).

Method

Participants

Twenty-six healthy students of psychology at the University of La Laguna participated in this study (20 women). The age range was 20 to 30 years, and the average age was 22.6 years. All participants were right-handed, with an average score of 0.85 in the Edinburgh Handedness Inventory, and had normal or corrected-to-normal visual acuity. They were checked to rule out any neurological and psychiatric conditions. Each participant received 10 euros after signing a written informed consent. Three participants were excluded from the analysis, two for an excess of artifacts in ERP signals and one due to a computer problem in the experimental session.

Stimuli

Examples of sentence stimuli are shown in Table 1. We selected 160 experimental sentences (80 for approach and 80 for avoidance), from a pool of 220 sentences that we had elaborated from approach/avoidance sentences in Gámez and Marrero (2001), which presented person and thing names as predicates. There were things that referred to objects (bread, meat, receipt, picture, . . .), and things in a more general sense (news, electric light, strike, volume, . . .). Proper names were selected from the most frequent names in lists of students studying psychology at the University of La Laguna. One half

of target proper names were female names and the other half were male names. Sentences were completed with two nouns that added some contextual details aimed at avoiding sentences ending with the target, and to give them a contextual meaning. Verbs were in past tense, indicating that actions took place, to highlight readiness for action encoding. Forty filler sentences were also elaborated with a similar structure and length as the experimental ones, using mental verbs.

Stimuli were evaluated for several relevant features, which affect the sentences in some cases and the target words in others.

Norming studies of sentences

We evaluated the action direction involved in the experimental sentences. To do this, 38 participants, none involved in the main experiment, evaluated sentences referring to persons in a version of the task (18 participants) and to things in the other task version (20 participants). They were told to evaluate the direction (approach or avoidance) of pairs of sentences with the same target. In the instructions, approach was described as the action having the sense of approaching the person/thing toward oneself, or the approach of oneself toward the person/thing, either physically or affectively, and involves a positive attitude. Avoidance was described as the action having the sense of keeping a person/thing away from oneself, or keeping oneself away from the person/thing, either physically or affectively, and involves a negative attitude. Motivational direction was correctly identified 97.92% of times in the case of person sentences. Likewise, motivational direction in thing sentences was correctly identified 98.37% of times.

Moreover, we evaluated valence and arousal in approach/avoidance sentences (see Kurdi, Lozano, & Banaji, 2016). Valence was described as situations related to the sentences referring to something positive or negative; positive represents good things to us (benefits, happiness, well-being, . . .), and negative represents bad things to us (damages, sadness, discomfort) on a 1 (*positive*) to 5 (*negative*) rating scale. Arousal was described as the level of excitement that we feel for the

Table 1 Examples of the Spanish experimental sentences in the different versions, and approximate translation in English

EXAMPLES	CONDITION
Example 1	
Victor prefirió a Paula en la fiesta de graduación (Victor preferred Paula at the graduation party)	approach-person
Victor desdeñó a Paula en la fiesta de graduación (Victor spurned Paula at the graduation party)	avoidance-person
Victor prefirió la carne en el menú de cafetería (Victor preferred the meat on the cafeteria menu)	approach-thing
Victor desdeñó la carne en el menú de cafetería (Victor spurned the meat on the cafeteria menu)	avoidance-thing
Example 2	
Elvira potenció a Ricardo en el equipo de trabajo (Elvira boosted Ricardo in the work team)	approach-person
Elvira debilitó a Ricardo en el equipo de trabajo (Elvira weakened to Ricardo in the work team)	avoidance-person
Elvira potenció el volumen de su equipo de radio (Elvira boosted the volume of her radio equipment)	approach-thing
Elvira debilitó el volumen de su equipo de radio (Elvira weakened the volume of her radio equipment)	avoidance-thing

situation on a 1–5 scale ranging from *exciting* to *calm*. Twenty raters, none of them involved in the main experiment, evaluated sentence valence and subsequent arousal in thing sentences. Valence of approach sentences ($M = 1.94$, $SD = 0.32$) was rated as “slightly positive” while valence of avoidance sentences ($M = 3.99$, $SD = 0.33$) was rated as slightly negative. The difference ($M = 2.05$) was significant, $t(19) = 15.28$, $p = .000$. In the case of arousal, approach sentences ($M = 2.70$, $SD = 0.48$) and avoidance sentences ($M = 2.67$, $SD = 0.46$) was similarly rated between “slightly exciting” and “neither exciting nor calm”.

In the case of person sentences, nineteen raters, none of them involved in the main experiment, evaluated sentence valence and arousal. Valence of approach sentences ($M = 1.81$, $SD = 0.41$) was rated as “slightly positive” whereas valence of avoidance sentences ($M = 4.21$, $SD = 0.43$) was rated as “slightly negative.” The difference ($M = 2.39$) was significant, $t(18) = 12.53$, $p = .000$. Likewise, arousal of approach sentences ($M = 3.10$, $SD = 0.77$) was evaluated as “neither exciting nor calm,” and arousal of avoidance sentences ($M = 2.18$, $SD = 0.53$) was rated as “slightly exciting.” The difference ($M = 0.92$) was significant, $t(18) = 3.89$, $p = .001$. By contrast, between person and thing sentences, there were no significant differences in valence either in approach or avoidance sentences. Likewise, there was not a significant difference in arousal in approach sentences. In the case of avoidance sentences, person sentences ($M = 2.18$, $SD = 0.53$) were evaluated as slightly more exciting than thing sentences ($M = 2.67$, $SD = 0.46$), significantly ($\text{diff} = 0.49$), $t(37) = 3.01$, $p = .005$.

As can be seen, there is a correlation between approach and avoidance sentences and their valence. This correlation is in accordance with Lang’s (Lang, Bradley, & Cuthbert, 1990) proposal that approach is associated with positive valence as it is conceived as directed toward pleasant targets, whereas avoidance is associated with negative valence as it is conceived as directed toward unpleasant targets.

Finally, 60 participants, none of them involved in the main experiment, evaluated the imageability of approach and avoidance sentences in the thing and person versions on a rating scale from 1 to 5. Each participant rated only 50 sentences, and an average of 20 responses was obtained for each item. Averaged imageability was as follows: approach-person ($M = 3.10$, $SD = 0.73$), avoidance-person ($M = 3.02$, $SD = 0.68$), approach-thing ($M = 3.19$, $SD = 0.70$), and avoidance-thing ($M = 3.25$, $SD = 0.70$). *T*-test contrasts did not find differences between thing and person sentences, $p > 0.05$.

Norming studies of targets

We also evaluated the congruence and probability of each target in the context of the experimental sentences. Participants were told to rate on a scale of 1 to 5 the

congruence of the target with the previous action verb (“if the sentence has sense in everyday life”) from *incongruent* to *congruent*, and subsequently its probability of occurrence with the action indicated by the verb in every day actions from *improbable* to *probable*. Each version of the sentences was evaluated by different raters, none of them involved in the main experiment: approach-person: 19, avoidance-person: 20, approach-object: 19, avoidance-object: 20. In the context of person sentences, targets were rated on average as moderately congruent to congruent both in approach ($M = 4.21$, $SD = 0.37$) and avoidance ($M = 3.89$, $SD = 0.37$) sentences, and the difference between both task versions was not significant, $p > 0.05$. In the case of target probability, targets were similarly evaluated in approach ($M = 3.59$, $SD = 0.45$) and avoidance ($M = 3.62$, $SD = 0.40$) sentences.

In object sentences, targets were rated on average as moderately congruent to congruent both in approach ($M = 3.74$, $SD = 0.64$) and avoidance ($M = 3.59$, $SD = 0.50$) sentences, and there was no significant difference between either task versions, $p > 0.05$. In the case of target probability, targets were evaluated as moderately probable, and there was not a significant difference between approach ($M = 3.48$, $SD = 0.53$) and avoidance ($M = 3.20$, $SD = 0.49$) sentences, $p > 0.05$.

We also evaluated valence and arousal. Twenty raters, none of them involved in the main experiment, evaluated valence and subsequent arousal to thing targets. Valence ($M = 2.36$, $SD = 0.29$) was rated between “slightly positive” and “neither positive nor negative.” Likewise, target arousal ($M = 2.57$, $SD = 0.43$) was rated between “slightly exciting” and “neither exciting nor calm.” Likewise, 20 raters evaluated valence and arousal to person name targets. Valence ($M = 2.45$, $SD = 0.37$) was rated between “slightly positive” and “neither positive nor negative.” Likewise, target arousal ($M = 2.85$, $SD = 0.42$) was rated close to “neither exciting nor calm.” There were no significant differences between person names and thing targets either in valence or arousal, $p > 0.05$.

In addition, forty raters (none of them involved in the main experiment) provided an estimation of the cloze probability of targets (20 raters for thing and 20 for person targets). Cloze probability refers to the predictability of the target word based on the prior context: Targets were omitted from the experimental sentences, and subjects were asked to finish them. We found that cloze probability was close to zero in the four types of sentences: approach/thing ($M = 3\%$, $SD = 0.01$), avoidance/thing ($M = 1\%$, $SD = 0.01$), approach/person ($M = 0.5\%$, $SD = 0.01$), avoidance/person ($M = 0.5\%$, $SD = 0.006$).

Finally, lexical factors (length, frequency and syllabic length) were checked for the target words in the sentences. No significant differences were found among conditions in any pairwise comparison, all $ps > 0.05$.

Design and procedure

A 2×2 within-subjects factorial design was used, with Direction (approach and avoidance) and Target (person and thing) as factors.

Participants were told to read sentences that appeared while seated in front of a computer screen. Sentence presentation was word by word following the scheme shown in Fig. 1. They were given 200 sentences, 40 for each experimental condition and 40 filler sentences. One third of the sentences (66) were immediately followed by a question on the content just read, which had either a positive or a negative response half of the time. The question remained on the screen for 3,000 ms or until a response was made. No feedback was given to the participants. These questions were aimed at keeping the attention of participants on the reading comprehension. There was a 3,500 ms interval between sentences presentations.

Participants were randomly assigned to one of the sets of sentences resulting from the counterbalance of the experimental conditions. This ensured that every participant received an equal number of sentences for each of the four conditions (approach-person, avoidance-person, approach-thing, avoidance-thing), and no participant received the same sentence twice. Sentences were randomly presented to the participants in each of the counterbalancing sets.

BIS/BAS scales

We used the Carver and White scales to measure individual differences in approach and avoidance trait that have been

reported as being effective in several studies (see Carver, 2006). The scales are a 20-item, four-point Likert-type measure composed of the following four subscales measuring BIS and BAS traits. First, BIS that has items that reflect concern and fear about the possibility of a bad occurrence, or sensitivity to occurrence. Second, there are BAS-reward responsiveness (BAS-RR) items that reflect responsiveness to reward. Third, BAS-drive (BAS-D) relates to the tendency to act quickly and strongly in pursuit of appetitive goals; and, finally, BAS-fun seeking (BAS-FS) refers to the tendency to seek out new potentially rewarding experiences. Respondents were asked to rate the extent of their agreement, from 1 (*strongly disagree*) to 4 (*strongly agree*). Internal consistencies of the scales ranged from good to excellent, and test–retest reliability, convergent and divergent as well as factorial validity were satisfactory in the studies of Carver and White. Further research has confirmed their standard as BIS/BAS measures (Carver, 2006; Caseras, Ávila, & Torrubia, 2003). In our study, the BIS scale was differentiated into two subscales: BIS-fear was composed of the two fear items of the original scale, and BIS-anxiety was composed of the other BIS items. We adopted this procedure following Corr and McNaughton (2008).

In the present study, the scales have the following alpha values: BIS-fear: 0.70, BIS-anxiety: 0.78, BAS-RR: 0.87, BAS-D: 0.51, and BAS-FS: 0.40. These values are acceptable, except in the case of BAS-FS.

EEG recording

EEG and EOG signals were recorded using Ag/AgCl electrodes mounted in elastic Quick-caps (Neuromedical Supplies,

Fig. 1 Scheme of one experimental trial

Compumedics Inc., Charlotte, North Carolina, USA). EOG signal was measured from two bipolar channels: one consisting of two electrodes placed at the outer canthus of each eye, another by two electrodes below and above the left eye. The EEG signal was recorded from 60 electrodes arranged according to the standard 10–20 system. All EEG electrodes were referenced online to an electrode at vertex and recomputed off-line against the average reference. EEG and EOG signals were amplified at a 500 Hz sampling rate using Synamp2 amplifier (Neuroscan, Compumedics Inc., Charlotte), with high- and low-pass filter set at 0.05 and 100 Hz, respectively. EEG electrode impedance was kept below 5 k Ω .

EEG data preprocessing was conducted using Edit 4.5 (Neuroscan, Compumedics Inc., Charlotte). The following transformations were applied to each participant's dataset. Data were initially low-pass filtered at 30 Hz. EEG segments were then extracted with an interval of 600 ms preceding and 800 ms following the onset of the critical target. On these segments, artifact rejection was performed in two steps. First, trials containing activity exceeding a threshold of $\pm 70\mu\text{V}$ at vertical and horizontal EOG and EEG channels were automatically detected and rejected. Second, nonautomatically rejected artifacts were manually removed, including trials with saccades identified over the horizontal EOG channel. For the computation of ERPs, artifact-free segments were averaged separately per subject and condition. A total of 8.2% of trials were excluded because of artifacts (mainly, eye blinks, drifts, and saccades). Baseline correction of averaged data was carried out using the time interval between 600 and 400 ms preceding the onset of the critical word. This time interval was chosen because of the different lexical elements just preceding person and thing nouns, a particle (*to*) and a determiner (e.g., *the*), respectively. With this choice, we wanted to avoid that ERPs elicited by target nouns were somehow contaminated by pretarget differences in the preceding elements. This could be due to raw differences between particles and determiners and also to processes related to the anticipation of the target type: a person after the particles, and a thing after the determiners.

ERP analysis

ERP waveforms were statistically evaluated using the cluster-based random permutation method implemented in Fieldtrip (Maris & Oostenveld, 2007); here applied to the 800-ms following the onset of the critical thing/person target. This method deals with the multiple comparisons in space and time by identifying, over the whole ERP segment (24,000 sample points: 400 time points and 60 channels), clusters of significant differences between conditions (sample points in close spatial and temporal proximity), while effectively controlling for Type I error.

This statistical approach was used to evaluate the effects of direction (approach vs. avoidance) on the ERPs elicited by thing and person nouns. Accordingly, two separate cluster-based randomization tests were conducted, one for thing nouns and another for person nouns. Furthermore, to evaluate the full 2×2 design, time segments and electrodes forming significant clusters were collapsed and submitted to repeated-measures ANOVA with direction and target as factors. This allowed us to detect if a significant effect of direction was specific to the involved target or if, on the contrary, it simply reflected an effect of approach versus avoidance that was independent of the target type.

Results

ERP results

For thing nouns, the comparison between approach and avoidance directions yielded a significant cluster around the time window of the N400 component (350–470 ms after target noun onset; $T_{\text{maxsum}} = 904$; $p < .025$; see Fig. 2a). This cluster reflected greater right frontal negative amplitudes for avoidance than for approach sentences (see Fig. 2b). Further ANOVA showed, in this cluster, an interaction between direction and target, $F(22, 1) = 14.05$, $p < .005$, $\eta^2 = .39$, which was apparently caused by the lack of significant effect of direction on person nouns. Thus, the effect in this right frontal N400 cluster seems to be specific to thing nouns ($p < .001$, $d = .89$).

There was also a significant cluster for the effect of direction on person nouns ($T_{\text{maxsum}} = 462$, $p < .05$). This cluster occurred in a later time window than the previous one (545–750 ms), and reflected larger negative amplitudes at left frontal sites for person nouns preceded by approaching verbs, relative to those preceded by avoidance verbs (see Fig. 2a–b). The ANOVA on collapsed amplitude values revealed effects of direction, $F(22, 1) = 10.06$, $p < .005$, $\eta^2 = .33$, and target, $F(22, 1) = 5.1$, $p < .05$, $\eta^2 = .19$, with larger negative amplitudes by person nouns than thing ones, and for nouns following approaching verbs than after avoidance verbs. The interaction did not reach significance, $F(22, 1) = 2.95$, $p = .09$, $\eta^2 = .12$, however, follow-up comparisons confirmed that the effect of direction was specific to person nouns ($p < .01$, $d = .62$). The topography of the ERP activity in this time window suggests that the cluster is reflecting a modulation of a sustained frontal negativity.

ERPs—BIS-BAS correlation analysis

Table 2 shows correlational analysis between mean amplitude of ERPs in the significant clusters for things and persons from voltage differences between approach/avoidance conditions, and BIS/BAS scales. One participant did not complete the BIS/BAS test.

Fig. 2 **a** Averaged ERP waveforms at electrodes representative of the anterior N400 and frontal negativity effects. *Gray shaded areas* highlight time window of significant interaction between target and direction. **b** Overview of cluster analysis results. Maps under label *minus* depict

scalp distribution of the differences between conditions. All other maps represent topography of the ERP activity for each condition. *White circles* in maps indicate the sites belonging to the significant cluster (Color figure online)

As can be seen, greater frontal negativity in approach-person sentences is associated with higher scores in fear, a subscale of the behavioral inhibition trait (BIS), and in BIS itself, though marginally significant in this case. In contrast, shorter frontal negativity in avoidance-persons sentences is associated with both higher scores in reward responsiveness, a subscale of behavioral approach trait (BAS), and in BAS itself. In addition, greater negativity of N400 in avoidance-thing sentences is associated with marginally significant higher BIS scores.

Discussion

As expected, we found ERP effects of direction (approach/avoidance) on components associated with word integration into ongoing sentence representation (Coulson, 2007; Huang et al., 2010; Kaan, 2007; Kutas, Van Petten, & Kluender, 2006; Kutas & Federmeier, 2011). Specifically, we observed approach/avoidance effects for thing names in an anterior N400-like component and for person names in a later component: a frontal negativity subsequent to N400. As noted (see

Table 2 Correlations between ERP measures and BIS/BAS scales in the significant clusters for things and persons to approach/avoidance difference

	APPROACH-PERSON (N545–750)	AVOIDANCE-PERSON	APPROACH-THING (N400)	AVOIDANCE-THING
BAS_DRIVE	.316	.160	.187	.152
BAS_FUN- S.	.078	.152	.015	-.045
BAS_RR	.112	.559* ($p = .016$)	.110	.025
BIS_FEAR	-.437* ($p = .042$)	.117	-.0168	-.0310
BIS_ANXIETY	-.283	.294	-.260	-.357
BAS	.248	.442* ($p = .039$)	.158	.070
BIS	-.407 ($p = .060$)	.212	-.0228	-.362 ($p = .09$)

* $p \leq .05$

Introduction), this temporal dissociation might be motivated by the fact that proper (persons) names demand deeper processing than common names, as person names lack semantic content, and the name word should be wholly processed to access a multimodal representation for identification of name bearers (the reference of a person name; Wang, Zhu, et al., 2013). Accordingly, in our sentences, meaning construction for person name sentences seems to require more involvement of this referential processing, delaying, therefore, the direction effect (approach versus avoidance) on noun integration. By contrast, the difference between approach and avoidance sentences is already apparent around the N400 time window for thing nouns, suggesting in this case an integration process that relies preferentially on the semantic memory mechanisms typically attributed to this component. Overall, this sequential pattern of effects indicates that described action direction is incrementally incorporated into sentence processing, even though, as we will discuss below, approach and avoidance thing and person sentences were equivalent in other respects. In what follows, we first address nonmotivational alternative accounts for our ERP findings and then continue by considering ERPs' identification, in particular their frontal scalp distribution, and framing them into a broader cognitive-affective view. This leads us to the idea that approach and avoidance sentences are differentially processed because they reflect (or describe) the way these actions are performed and experienced in everyday life.

The N400 has been shown to be mainly sensitive to semantic incongruence and to other factors such as word frequency, word repetition, concreteness and expectancy or cloze-probability (Kutas & Federmeier, 2011). Less congruent or predictable targets from the previous context elicit greater N400 negativity. This contrasts with the modulation of N400 by approach and avoidance in our study inasmuch as it is not associated with target congruence or predictability, since our test of stimuli did not show significant differences in either factor between experimental conditions. Neither could this modulation be explained in terms of cloze probability, given the low cloze probability of targets in the experimental sentences. In the case of frontal negativity ERP to person name targets, it was also modulated by approach and avoidance direction: Approach caused more negativity than avoidance. As in the case of ERP for things, this effect cannot be attributed either to target congruence or predictability. Likewise, it cannot be explained in terms of cloze probability.

ERPs scalp frontal distribution

Also of interest is the scalp distribution of the ERPs modulated by approach/avoidance in both frontal areas. This contrasts with previous research in the case of N400, inasmuch as this ERP is usually distributed in the centroparietal electrodes (Kutas & Federmeier, 2011). However, other studies have

found a more anterior, frontocentral distribution of N400. For example, N400 effects for concrete words (in contrast to abstract ones) are stronger in frontal sites, which have a posterior distribution in the scalp (see Lee & Federmeier, 2008). More specifically, Martin-Loeches et al. (2012) found N400 with a more frontocentral distribution associated with semantic violations of positive words (adjectives). Likewise, Ding et al. (2015) found larger N400 over the left anterior region for emotional verbs (positive and negative) in contrast to neutral words. In addition, a more frontocentral distribution of N400 has been reported in action understanding either with tasks that involve observing actions or those that combine words with action planning (Amoruso et al., 2013; Van Elk, van Schie, & Bekkering, 2008). As can be seen, variability in topography of N400 is not exceptional. In fact, the main characteristic to identify an ERP as N400 is the amplitude and peak of the wave, two features that are very stable (Kutas & Federmeier, 2011), as occurs in this study. According to Voss and Federmeier (2011), different topographies of the N400 can be functionally identical.

Like common name sentences, person name sentences showed an N400 wave, and subsequently a sustained left frontal negativity lasting around 800 ms from target onset. As mentioned, this left frontal negativity could show the cost of building the meaning of sentences with person names in contrast to common names. In our study, person names were chosen from the more frequent names in the social ambit of participants (the university), and thereby were familiar to them. Plausibly, person names would automatically activate a multimodal representation associated with name bearers (Wang et al., 2013). Huang et al. (2010; see also Lee & Federmeier, 2008) showed a sustained frontal negativity, similar to some extent to that found in this study (and different from the N400 component), reflecting an imagery processing of words. Multimodal representation of person names could involve additional imagery processing, which would have produced this frontal negativity. In addition, we think that right/left anterior distribution of these frontal negativities could be associated with approach/avoidance processing, as the right frontal lobe has been shown to be specialized in avoidance and negative stimuli processing, whereas the left frontal lobe is specialized in approach and positive stimuli processing (see Davidson, 2004).

Affective ERP modulation

The affective approach/avoidance modulation of ERPs toward things and persons could reflect an interaction between language and affection in everyday action understanding. Previous ERP research has held that emotionality in words would constitute a lexico-semantic representation that recruits additional processing resources and gives priority to access semantic meaning, plausibly for adaptive reasons associated

with the value of positive and negative stimuli for individual survival (Ding et al., 2015; Holt et al., 2009; Martín-Loeches et al., 2012; Van Berkum, 2009). As mentioned, direction (approach and avoidance) like emotionality would constitute a semantic representation of targeted everyday actions to be processed with priority, monitored by our affective system, also plausibly for adaptive reasons: encoding direction of past actions toward environmental targets would be relevant to an adaptive regulation of individual behavior for subsequent interactions. In this context, the approach/avoidance modulation of ERPs would show the role of the affective system in modulating access to the meaning processing of motivational stimuli.

The type of modulation of approach and avoidance on processing action toward persons and things in sentences has been examined in this article. In accordance with our expectations, modulation of N400-like component in thing sentences could be the result of avoidance direction recruiting more resources than approach. To the contrary, approach/avoidance modulation of ERP for person name targets would reflect that approach recruits more brain resources for encoding than avoidance. These ERP modulations would be related to different adaptive implications of approach and avoidance. In the case of things, avoidance actions are aimed at distancing stimuli that we probably dislike (as negative for individual survival; see LeDoux, 1996). A quick response for removal of disliked things would depend on a deeper direction encoding of previous (recent) avoidance actions. In the case of persons, a deep encoding of approach in past actions would adaptively regulate subsequent (positive) interactions toward persons who we like (as surely being trusted for us). Likewise, regarding avoidance in thing sentences, larger N400 could plausibly be due to some degree of affective incongruity (see Holt et al., 2009), inasmuch as thing targets were evaluated between slightly positive and neither positive nor negative. Further research would then be necessary to examine the role of affective congruity in avoidance modulation of N400 in thing sentences found in this study.

Valence and direction

A relevant issue that we would like to consider is the relation between sentence valence and direction, as approach sentences were rated as positive and avoidance sentences as negative. Direction and valence, although conceptually different, correlate: We approach positive stimuli and avoid negative ones (Lang et al., 1990). So, approach events usually involve pleasant situations (i.e., “Victor preferred Berta”), whereas avoidance events usually involve unpleasant situations (i.e., “Victor disliked the video”). However, our ERP effects are difficult to explain in terms of valence in the light of prior research. As in the case of emotional words, we could expect emotional sentences to recruit more processing

resources than neutral sentences, and negative sentences more than positive sentences (Carretié et al., 2008; Díaz-Lago et al., 2015; Ding et al., 2016; Herbert et al., 2006; Herbert et al., 2008; Hinojosa et al., 2014; Holt et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2009; Martín-Loeches et al., 2012; Moreno & Rivera, 2013; Moreno & Vázquez 2011; Wang et al., 2013). As person and thing sentences did not differ in valence in the norming studies, we would expect in a passive reading task valence affecting both person and thing sentences: greater ERP amplitudes to negative in contrast to positive sentences. In contrast to this prediction, we have found different ERP modulation to person and thing sentences. Likewise, arousal was similarly rated in thing and person approach sentences, whereas avoidance sentences were rated as slightly more arousing for person than thing sentences. More emotionality could be associated with greater ERP amplitudes in the context of sentences (see Bayer, Sommer, & Schacht, 2010). However, we found greater ERP amplitude for approach than avoidance in person sentences.

Our experimental sentences describe social actions directed toward persons and things. Direction is described by the verbs as involving attitudes of approach/avoidance. Therefore, direction would be in the focus as an experiential component to be activated during simulation for understanding the action. In contrast, emotional experience would emerge associated with direction encoding, furnishing then valence to sentences: positive/pleasant in approach and negative/unpleasant in avoidance sentences. Taking this into account, ERP modulation dissociated for persons and things found in this study would be plausibly interpreted as an effect of direction encoding.

We have also explored correlations of approach/avoidance modulation of ERPs toward things and persons with individual differences in BIS (avoidance trait) and BAS (approach trait). We found associations of BIS with more negativity in approach-person sentences. Likewise, BAS is associated with less negativity in avoidance-person sentences. Participants with higher fear and BIS (avoidance trait) seem to use more cognitive processing to encode approach-person situations. By contrast, participants with higher BAS (approach trait) seem to use less cognitive processing to encode avoidance-person situations. These associations provide additional support to a motivational direction interpretation of our ERP effects, mainly in the case of person-sentences.

Contributions

In the field of language, it has been proposed that action understanding involves simulation that demands a multimodal integration of motor, affective, and cognitive components of action experience (see Amoroso et al., 2013). Previous research has supported this simulation process and

demonstrated the role of motor, emotional, and spatial representations in comprehension of linguistic materials. However, a potentially relevant aspect of everyday action to be simulated for understanding, direction (approach/avoidance), has received little attention. Our study has explored the understanding of approach and avoidance direction in everyday action language related to social and motivational scenarios by means of ERPs. As exploratory, our study has limitations. For example, the association of valence sentence and direction makes direction interpretation of ERPs modulation tentative to some extent. However, our study has focused on the role of direction, which is relevant to the field of action and emotional language. It also has proportioned stimuli and ideas that seem appropriate to enable future research to find more definitive empirical responses.

In the field of motivational and social cognition research, our results highlight the role of approach and avoidance in everyday actions beyond the well-established effect of approach/avoidance reactions toward stimuli. In relation to valence, previous research has found a negativity bias: greater processing of negative compared to positive stimuli (Crawford & Cacioppo, 2002; Ito, Larsen, Smith, & Cacioppo, 1998; Martín-Loeches et al., 2012; Smith, Cacioppo, Larsen, & Chartrand, 2003). In the case of action direction encoding, our study has contributed by showing there is a bias toward encoding approach in actions to persons that are verbally described.

Conclusions

To sum up, our findings widen scientific knowledge of the neural basis of social, affective, and motivational understanding of action language for everyday actions. They highlight the basic role of encoding approach/avoidance direction to understand everyday actions, and the importance of distinguishing targets, either persons or things. Beyond these findings, several relevant questions are open to further research. In particular, the relation between direction, valence, and arousal of targets in verbal comprehension of everyday actions should be investigated. A deeper understanding of the role of individual differences in approach/avoidance personality traits would be also of interest. Another avenue of research could be the role of hemispheric asymmetry in this process or the role of motor processes in encoding approach and avoidance direction by means of spectral analysis of the brain wave.

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