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REGULAR ARTICLE

Language comprehension may depend on who you are: how personality traits and social presence seemingly modulate syntactic processing

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ABSTRACT
Although it has been scarcely investigated, personality might help shape language comprehension during social interaction. The aim is to investigate how differences in personality might affect morphosyntactic processing and whether it may be affected by social presence. In a correctness judgement task, participants read sentences that were correct or contained a morphosyntactic error, either while alone or in the mere presence of a confederate. Participants' NEO-FFI personality inventory scores were used to analyse behavioural, and event related potential data. Neuroticism and Extraversion interacted with error rate and reaction time, while Conscientiousness only interacted with reaction time. A weak N400-like component to morphosyntactic anomalies was triggered for introverts in the social presence condition, compared to a LAN in the alone one, while a LAN was triggered in both conditions for extraverts. Whereas higher Conscientiousness was related to a stronger LAN and a weaker P600 component, lower Conscientiousness reflected the opposite pattern.

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Personality; social presence; ERP; morphosyntactic processing; LAN

Introduction

Personality psychology addresses individual differences in behaviour, emotion, motivation, and cognition (DeYoung et al., 2010). While it is well established that personality may help mediate our responses to our environment, the extent to which it accounts for individual differences in cognitive processes, particularly in language, is still understudied.

The Big Five model is the most widely used taxonomy of personality (DeYoung & Blain, 2020), categorising trait descriptors into five broad domains comprised of underlying sub-facets (Costa & McCrae, 1992): Extraversion, Neuroticism, Openness to experience, Agreeableness and Conscientiousness. Extraversion, the tendency toward positive affectivity (Brower et al., 2015), affects how active and sociable, or how reserved and passive individuals are (Roslan et al., 2017). Neuroticism is understood as the tendency toward negative affectivity, emotional distress, anxiety, and higher threat assessment (Costa & McCrae, 1992; McCrae & Costa, 1987). Openness to experience is related to cognitive and perceptual flexibility, imagination and intellectual engagement (DeYoung et al., 2005; DeYoung & Blain, 2020). Agreeableness describes one's regard for the rights and wishes of others, and the tendency to be compliant, polite and compassionate as opposed to aggressive and insensitive (DeYoung & Blain, 2020). Lastly, Conscientiousness refers to a range of constructs that reflects the propensity to be self-controlled, responsible towards others, hardworking, orderly, and rule-abiding (Jackson & Roberts, 2017). Brain-imaging studies have linked variation in regional volume differences with four of the Big Five traits, potentially highlighting biological bases associated with these traits (DeYoung et al., 2010; DeYoung & Blain, 2020; Schmidtke & Heller, 2004). Recently, researchers were able to predict participant's scores on Big Five traits based on brain activity analysis while they watched emotional film clips (Zhao et al., 2017).

Currently, there is little understanding as to personality's relationship with language comprehension – a valid question given that language networks do not function in isolation but rather are subject to influence by various extra-linguistic factors such as mood, emotions, speaker

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characteristics, actions, and presence (Casado et al., 2018; Hinchcliffe et al., 2020; Pulvermüller & Fadiga, 2016; Tesink et al., 2009; Van Berkum et al., 2013; van den Brink et al., 2012; Willems & Casasanto, 2011). Indeed, while various findings imply that personality does impact speech production (Hubert, 2020; Hubert & Järvikivi, 2019; Park et al., 2015; Pennebaker & King, 1999; Yarkoni, 2010) and also phonetic convergence in English L2 learners (Lewandowski & Jilka, 2019), few studies have honed in on how personality intervenes in language processing and particularly in syntax. An important question in psycholinguistic research which should be explored in order to fully understand the language machinery and its functional significance in relation with other human brain processes.

Boland and Queen (2016) recently found that certain Big Five personality traits (namely Extraversion, Agreeableness, and Conscientiousness) affected how likely participants were to either ignore or be sensitive to formal versus informal written language errors, suggesting that certain errors may be interpreted as having different social implications according to one's personality. Another study observed correlations between reaction times when responding to morpho-syntactic, semantic/pragmatic, and identity-clashing violations, and scores in Openness, Conscientiousness, Extraversion and Neuroticism (Hubert, 2020). Recent research by the same authors revealed an effect of Neuroticism on the processing of simple morpho-syntactic errors by using pupillometry, whereby higher Neuroticism scores were correlated with a larger dilatation to morpho-syntactic errors, as compared to lower scores on this scale (Hubert, 2020; Hubert & Järvikivi, 2019, 24-27 july). dark forces in language comprehension: the case of neuroticism and disgust in a pupillometry study proceedings of the 41st annual meeting of the cognitive science society, montreal, qc). While these findings support a potential relationship between personality and language processing, none take into account the ways in which personality interacts with context. In line with Revelle's (1993) position that "individual differences combine with situational manipulations to affect the availability and allocation of cognitive resources", one might expect that different social circumstances may interact with personality in order to affect language processing.

Given its temporal resolution, Event-Related brain Potentials (ERP) is a common technique used to study language processing. Psycholinguistic research upholds that there is an early stage of (mostly) parallel semantic and syntactic processing (represented in part by the N400 and LAN components, respectively) succeeded by a later integration stage (P600 component) that allows interaction between different types of information (Molinaro et al., 2011; Steinhauer & Connolly, 2008). The negative centro-parietal fluctuation around 400 ms (N400) in response to semantic errors is understood as a fundamental indicator of semantic processing (Kutas & Federmeier, 2011) and likely represents the amount of resources needed to integrate word meaning into a current context (Wang & Knosche, 2013). The left anterior negativity (LAN) component (100–500 ms), associated with first-pass parsing (Hahne & Friederici, 1999) has been reported for grammatical anomalies including morphosyntactic violations (e.g, number violations and subject-verb violations) (Steinhauer & Connolly, 2008). Lastly, the later (600–1000 ms) centro-parietal positive component (P600) reflects a more general marker for structural processing and reanalysis due to morphosyntactic violations (Molinaro et al., 2011; Steinhauer & Connolly, 2008), while the "semantic P600", that is triggered by semantic anomalies instead of syntactic ones, is linked to the evaluation of the veridicality of one's analysis (van Herten et al., 2005) and the assessment of incoming information to update the mental model (Burkhardt, 2007).

Previously, we found that language processing (specifically, ERP responses to semantic and syntactic errors) was affected by social presence when participants performed a language correctness task in the presence of a confederate, as opposed to when they were alone (Hinchcliffe et al., 2020). Overall, the presence condition was associated with a more centro-posterior LAN component (interpreted as an N400). The results seem to imply a boosting of heuristic language processing strategies characteristic of lexico-semantic operations, which entails a shift to the morphosyntactic violations processing strategy that is typically based on algorithmic or rule-based strategies. Whereas the heuristic processing style is more holistic, not taking all available information into account while relying on shortcuts and previous knowledge, algorithmic processing engages more detailed, systematic and rule-based strategies. Personality traits have been related with the use of heuristic strategies and decision-making (Belhekar, 2017; Haley & Stumpf, 1989; Martin-Loeches et al., 2009; Vissers et al., 2013). In this regard, high Conscientiousness is characterised by the propensity towards rule-abiding (Jackson & Roberts, 2017), promoting rule-based strategies, while low Conscientiousness might promote the use of heuristic strategies. Furthermore, personality is considered by some authors to be an important contributor in explaining social presence effects (Aiello & Kolb, 1995). Though personality's role in social facilitation is typically framed around Extraversion and

Neuroticism and their interaction with self-esteem (Uziel, 2010), it is plausible that other factors may also influence the response to social presence. For example, co-representation studies indicate that people tend to monitor others' performance and remember what their co-actor needs to be doing throughout the experiment, even when it impairs one's performance or is not required to perform one's own task (Bockler et al., 2012). Along these lines, it is plausible that the extent to which people are compassionate (Agreeableness), task-driven (Conscientiousness), and/or willing to try new things (Openness) could also impact the degree to which they are affected by the presence of another person and how they interpret aspects of social presence in general.

It is important to better comprehend the ways in which individual differences, including personality, contribute not only to social facilitation effects, but also to language processing. The present study aims to explore whether personality may be related to differences in language processing in terms of ERPs with a specific interest in morphosyntactic processing, which, although traditionally thought of as encapsulated (Fodor, 1983; Hauser et al., 2002) has been shown to be influenced by external factors (Casado et al., 2018; Hinchcliffe et al., 2020; Verhees et al., 2015; Vissers et al., 2010). Along these lines, the present study also intends to investigate the potential relationship between personality traits and behavioural and psychophysiological measures, and how these interactions might differ according to social context. To this aim, participants read sentences that could contain syntactic anomalies while being either alone or in the mere presence of a confederate. They also completed the NEO Five Factor Inventory (NEO-FFI) (Costa & McCrae, 1992) in order to explore processing differences as a function of personality traits.

We expect personality-related modulations of language comprehension components both in the alone and in the mere presence conditions, since previous literature, though scarce, described influences of personality traits on language processing. Regarding the skin conductance response, we predict larger skin conductance levels in the social presence condition than in the alone condition, specifically for low extrovert participants when judging syntactic anomalies. In addition, given that correlations between reaction times and personality traits such as Openness, Conscientiousness, Extraversion and Neuroticism have been previously reported for a morphosyntactic task (Hubert, 2020), we also expect error rate and reaction time modulation amongst personality traits. Modulations of amplitude and topography are also expected in the syntax-related component. In this regard, a high level of Conscientiousness involves higher rule abiding, potentially promoting a rule-based strategy, which has been related with more anterior component topographies. In contrast, lower Conscientiousness might result in a more centro-parietal component distribution. Furthermore, according to the personality and language research reviewed above, personality modulations of syntax processing might be expected to differ in the mere presence condition. Specific predictions are hard to establish, given the variety of possible causes for social presence effects (for a detailed discussion see (Hinchcliffe et al., 2020)); while Extraversion and Neuroticism are expected to interact with social presence effects to some degree (Aiello & Kolb, 1995), effects of other personality traits would not be unexpected.

Materials & methods

Participants

Twenty-eight female and two male ($n = 30$) Spanish-speaking University Students (mean age = 22.5, SD = 2.7) participated in the study after giving informed consent according to the Declaration of Helsinki and with the approval of the ethics committee of the Complutense University. Ultimately, data from one (female) participant was excluded from personality-related analyses following their incorrect completion of the NEO-FFI, yielding analyses from a total of 29 participants. All participants had self-reported normal or corrected-to-normal vision, no history of neural or cognitive disorders. They were not on antipsychotic medications, tricyclic antidepressants medication in the 3 months prior to the study, no NSAIDs, opioids, corticosteroids, anxiolytics medication, presence of pain, or any disease symptom in the last 24 h prior to the study. They were all right-handed ($M = 78.90$, $SD = 21.90$), according to the Edinburgh Handedness Inventory (Oldfield, 1971), and did not have reading difficulty. In order to be included, participants had to be native Spanish speakers and have lived in Spain for at least five years prior to the study in order to be familiar with the vocabulary utilised in the language task.

Materials

In order to measure personality, participants completed a validated Spanish version (Cordero et al., 1999) of the NEO Five Factor Inventory (NEO-FFI) (Costa & McCrae, 1992), a shorter version of the Revised NEO Personality Inventory which includes a total of 60 items (12 per domain). The scale measures five main domains:

Table 1. Types and examples of sentences used in the experimental procedure.

Short Sentences	Determiner	Noun	Adjective	Verb	Complement	
Correct	Los	momentos	críticos	pasan	rápido.	
	The	*moments*	*critical (m.)*	*pass by*	*quickly.*	
Syntactic Anomaly (Gender)	Los	momentos	**críticas**	pasan	rápido.	
	The	*moments*	*critical (f.)*	*pass by*	*quickly.*	
Long Sentences	Determiner	Noun	Adjective	Verb	Preposition	Complement
Correct	La	empleada	desinteresada	alegra	al	jefe.
	The	*employee*	*selfless*	*pleases (sg.)*	*the*	*boss.*
Syntactic Anomaly (Number)	La	empleada	desinteresada	**alegran**	al	jefe.
	The	*employee*	*selfless*	*pleases (pl.)*	*the*	*boss.*

Notes: Literal translations (noun-adjective order inverted) into English, where m., masculine; f., feminine; sg., singular; pl., plural. Bold words represent syntactic anomalies.

Neuroticism, Extraversion, Openness to experience, Agreeableness, and Conscientiousness.

The language material consisted of 200 experimental Spanish sentences plus fillers (100 correct and 100 syntactic incorrect). Each experimental sentence, which was originally correct, was modified to form an incorrect version of the sentence containing a syntactic anomaly. The same sentences were used in Hinchcliffe et al. (2020), half of which were also used in a previous experiment (Jiménez-Ortega et al., 2017). Both short sentences (determiner-noun–adjective-verb-complement) and long sentences (determiner-noun–adjective-noun-preposition-complement) exemplified structures commonly used in Spanish (see Table 1 for examples). The fillers were also long and short sentences, with structures other than those used in the experimental sentences. These fillers served to increase the structure variability of the sentences as well as the location and type of linguistic errors.

The syntactic anomaly could be presented in the adjective or in the verb. Syntactic violations in the adjective consisted of either a gender violation or a number violation, whereas in the verb they were always a number violation. Frequency, valence, and length of critical words were not counterbalanced, as they were used in all conditions. In total, three different sets of sentences were composed, containing different combinations of sentences and avoiding the repetition of an experimental sentence within a given set. They were counterbalanced according to gender, number and location of the anomaly (i.e. in the adjective or verb), and sentence length. Additionally, each presentation set was divided into two halves, one for the alone condition, the other for the social presence condition. Subjects saw each experimental sentence only once, only in one version, and only in one condition (social/alone). Although each presentation set was presented to ten participants, yielding a total sample of 30 participants, one participant did not correctly complete the NEO-FFI, leading to a final total of 29 participants included in the analyses.

Procedure

Participants were seated in a quiet, isolated room approximately 70 cm in front of an LCD screen, with visual angles around 0.8° to 4°. Each trial began with a fixation cross (500 ms) in the centre of the screen, followed by the rest of the sentence, presented word by word in the centre of the monitor. Each word was presented for 200 ms, with an inter-stimulus-interval of 300 ms (Figure 1). All writing was presented in white letters against a black background using 30-point Arial font. The first word of each sentence started with a capital letter, and the last word was followed by a period. One second after the sentence finished, a question mark was presented in the centre of the monitor for 1.5 s, during which time the participant indicated the sentence's correctness by pressing one of two buttons. The hand used for this task was counterbalanced across subjects. In order to avoid ocular artifacts during the electroencephalogram recordings, participants were asked not to blink in the time between the fixation cross and the question mark.

Both conditions of the experiment were carried out on the same day, each lasting about 30 min. In the social condition, a confederate was seated approximately 55 cm to the participants' right, such that the confederate was within the participant's peripheral vision (see Figure 2). The confederate was always of the same sex as the participant and posed as a university student. The researcher explained the confederate's task in front of the participant, explaining that the confederate was participating in a trial run for an experiment on memory. The confederate, who was an actor, was audibly instructed to read the sentences being presented in order to later complete a recognition memory task, in which they would indicate which sentences had been presented. In order to seem

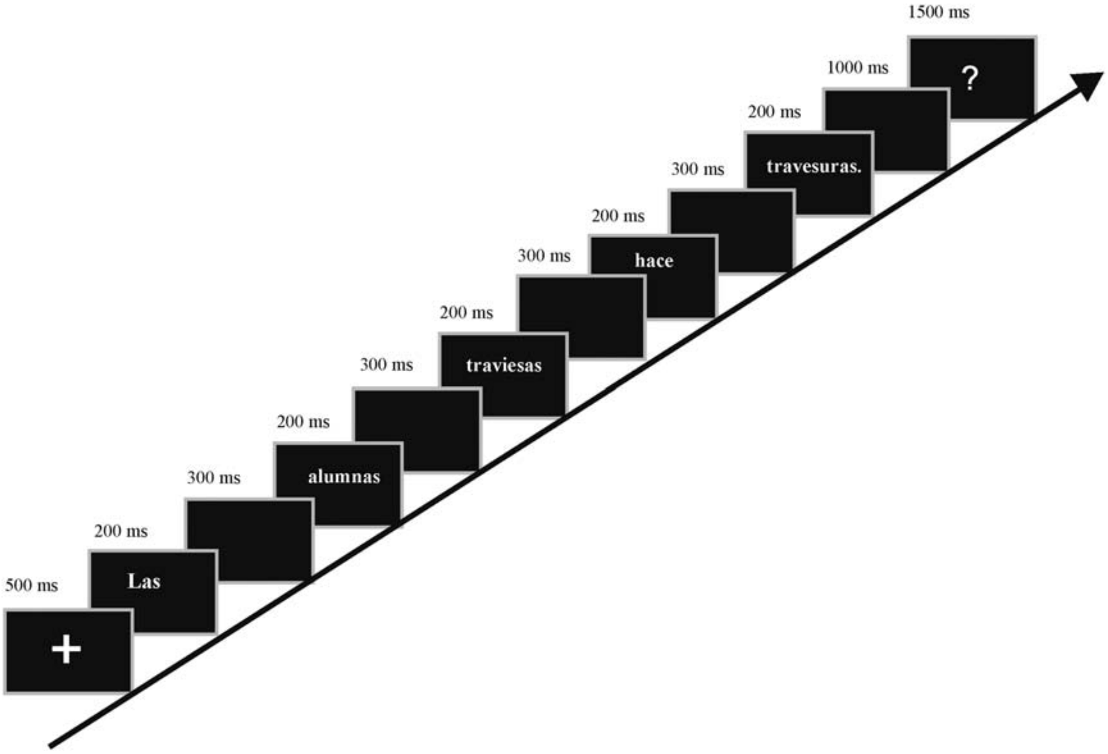

Figure 1. Schematic representation of the procedure: Each word in a sentence was presented for 200 ms. The sentence could be correct or could have a syntactic (number or gender) disagreement in the adjective or in the verb. In this example, the syntactic anomaly was in the verb (literal translation: the naughty students *makes* mischief).

Figure 2. Photographs of the physical arrangement during both conditions. Left: alone condition, where the participant sat alone approximately 70 cm in front of the screen. Right: social presence condition, where a confederate sat approximately 55 cm to the participant´s right side, in the participant´s field of peripheral vision.

realistic, the researcher showed them both an example of what the memory questionnaire would look like. Once the participant understood the task, they completed a short training consisting of 24 representative sentences which were not later included in the experiment. The order of presentation of the social/alone conditions was counterbalanced across participants. After completing the study, the participant was given access to complete a validated Spanish version of the NEO-FFI (Cordero et al., 1999).

Throughout the experiment, we collected information regarding participants' arousal levels by means of skin conductance recordings. A Skin Conductance (SC) sensor was attached to the index and middle finger of the hand not being used to respond. In order to compare skin conductance means between conditions, subject data was first normalised. Individual measures of skin conductance recordings were averaged together for each participant separately, while the grand mean was assigned a value of 1. Therefore, skin conductance values in each social condition were compared in terms of standard deviations from the grand mean.

EEG and GSR recordings

The electroencephalogram was recorded using 61 electrodes according to the 10/20 International System. The right mastoid (M2) served as the on-line reference, recalculated off-line to M1–M2 average reference. Eye movements were recorded through electrodes placed above and below the left eye (VEOG) as well as on the outer corner of both eyes (HEOG). Electrode impedance kept below 5 KΩ. Skin conductance (SC) data were synchronously recorded with the EEG data through an 8-channel Multibox polygraph (IEEC 60601-1, GSR module, Brain Products, Munich).

The EEG and SC data were analysed with Brain Vision Analyzer® software. The continuous EEG recordings were divided into segments of 1200 ms, starting 200 ms to onset of the critical word (adjective or verb). All EEG data was recorded with a 0.01–100 Hz band-pass and offline filtered with a 0.1–30 Hz band-pass filter. Ocular artifacts were corrected through Independent Component Analyses (ICA). Epochs exceeding ± 100 µV and epochs that contained artifacts were eliminated. The resulting epochs were included both in the EEG and GSR analyses.

Results

Analysis

Both repeated ANOVA and Linear Mixed models' analyses were calculated, taking in account the advantage and disadvantages of each one. Although linear model analyses can incorporate continuous predictors such as personality traits into their calculations (Gelman & Hill, 2007), there is not yet a common agreement about how topographical factors should be treated in such analyses (for different approaches see: Caffarra et al., 2019; Nickels et al., 2013). While Repeated ANOVA analyses allow statistical comparison, topographic and wave representations of high vs. low personality traits and they also maximise comparability with previous studies on language and social presence (Hinchcliffe et al., 2020), although they imply certain loss of information and power.

Repeated measures ANOVA analyses

Based on their scores on the adapted version (Cordero et al., 1999) of the NEO-FFI (Costa & McCrae, 1992), participants were grouped according to whether their score was below or above the median score for that trait (see Table 2 for distribution). Participants with a score equal to the median were assigned to the group above the median.

For statistical analyses of the ERP, clusters of electrodes constituting six regions of interest (ROI) were constructed. The ROIs were composed as follows: Left Anterior (F5, F3, F1, FC5, FC3, and FC1 electrodes), Right Anterior (F2, F4, F6, FC2, FC4, FC6), Left Central (C5, C3, C1, CP5, CP3, CP1), Right Central (C2, C4, C6, CP2, CP4, CP6), Left Posterior (P5, P3, P1, PO3), and Right Posterior (P2, P4, P6, PO4). The repeated-measures ANOVAs included five factors: Hemisphere (left, right), Region (anterior, central, and posterior), Correctness (correct and incorrect), Social Presence (social, alone). All Big Five personality traits were used as dichotomous inter-subject factors. Violations of the sphericity assumption were corrected, when necessary, by the Greenhouse-Geisser method, and *post hoc* tests were corrected by the Bonferroni method.

Time windows were elected following visual inspection of the waveforms. The 400–500 ms window was used to analyse the left anterior negativity (LAN) component, and the 600–800 ms window was chosen to analyse the P600 syntactic component. Although the 600–700 ms and 700–800 ms windows were explored separately, using these smaller windows did not significantly change the overall results. As such, the 200 ms window was used for simplicity.

Linear mixed model analyses

Linear mixed models were calculated in SPSS 22 using the same time windows and ROIS used in the repeated ANOVA. Each time window was analysed by first fitting a linear mixed effect model and then subjecting the resulting model to a type 3 ANOVA analysis, with

Table 2. participant distribution into groups based on NEO-FFI medians.

Big five trait	Overall participant median ($n = 29$)	Participants with mean scores below the median (Group 0)	Participants with mean scores above the median (Group 1)	Participants with same mean as the median
Neuroticism	21	14	15	1
Extraversion	32	13	16	2
Openness	28	13	16	2
Agreeableness	32	13	16	3
Conscientiousness	34	14	15	4

Notes: Participants with the same mean as the group median were assigned to group 1. Scales range: 0–48.

Table 3. Results of *t*-tests comparing means for low and high groups for each NEO trait.

Big five trait	Spanish university students mean	Participants mean	*t*-value	D.F.
Neuroticism	23.48 (sd = 8.26)	21.52 (sd = 6.91)	−1.51 (*p* = .141)	28.94
Extraversion	33.09 (sd = 6.68)	31.67 (sd = 7.07)	−1.08 (*p* = .290)	28.58
Openness	28.68 (sd = 6.63)	28.87 (sd = 6.26)	.16 (*p* = .872)	28.73
Agreeableness	30.20 (sd = 5.80)	30.91 (sd = 4.95)	.76 (*p* = .450)	28.90
Conscientiousness	29.14 (sd = 6.91)	31.00 (sd = 6.10)	1.63 (*p* = .114)	28.84

Notes: Means of participants of this study and Spanish university students (Cordero et al., 1999) were compared by a summary independent *t*-test. Equal variances not assumed.

Table 4. Results of t-tests comparing means for low and high groups for each NEO trait.

Big five trait	High	Low	*t*-value	D.F.
Neuroticism	*M* = 28.07 (SD = 4.57)	*M* = 16.64 (SD = 2.76)	8.20***	23.26
Extraversion	*M* = 37.38 (SD = 4.23)	*M* = 26.54 (SD = 4.93)	6.275***	23.82
Openness	*M* = 34.06 (SD = 4.25)	*M* = 23.92 (SD = 2.78)	7.72***	25.97
Agreeableness	*M* = 35.06 (SD = 2.52)	*M* = 26.69 (SD = 2.72)	8.52***	24.87
Conscientiousness	*M* = 36.40 (SD = 2.17)	*M* = 26.57 (SD = 4.60)	7.27***	18.20

Notes: I-values with *p* (*<.05, **<.01, ***<.001) and degrees of freedom. Equal variances not assumed.

denominator degrees of freedom estimated by Satterthwaite's approximation. The latter step was done introducing traits one by one, in order to provide sufficient cases for effects and/or interactions to fit the model.

Personality data

The participants' mean scores, compared to university students in the general population as a comparative reference sample for our group of participants, can be seen in Table 3. Our sample was similar to the Spanish University population (Cordero et al., 1999) as no significant differences between participants and the reference sample were observed (all Ts < 1.63, all ps > .1).

Independent samples *t*-tests comparing the means for low and high groups in each NEO factor confirmed that for each trait the two groups differed significantly (see Table 4).

Behavioural data

Behavioural data repeated ANOVA analyses indicated an overall Correctness effect on error rate ($F(1,9) = 17.56$, $p = .002$, $\eta_p^2 = .661$, $\theta = .960$), with a significantly higher error rate for correct sentences ($M = .330$, SE = .03) than for syntactic anomaly sentences ($M = .121$, SE = .04; Δ = .21, SE = .053, $p = .003$). Along these lines, there was a significant Correctness effect on reaction time as well ($F(1,9) = 16.33$, $p = .003$, $\eta_p^2 = .645$, $\theta = .948$), due to a longer reaction time for correct sentences ($M = 524.13$, SE = 26.54) than for syntactic anomaly sentences ($M = 457.25$, SE = 22.87; Δ = 66.87, SE = 16.52, $p = .003$). However, analyses did not reveal a main effect of Social Presence Condition on either error rate (all Fs < .757, all ps > .1) or reaction time (all Fs < 3.14, all ps > .1). Additionally, NEO scores did not appear associated with differences in neither reaction time nor error rate; reaction time analyses revealed no interactions with NEO scores and social condition (all Fs < 3.84, all ps > .09) nor sentence type (all Fs < .734, all ps > .4), and error rate analyses revealed no interactions between NEO scores and social presence condition or sentence type, either (all Fs < 2.96, all ps > .12; all Fs < .875, all ps > .37, respectively).

Linear mixed models were calculated for both error rates and reaction times, introducing Presence, and Correctness as repeated factors, and the five personality traits as covariates. For error rates, significant differences were observed for Correctness ($F(1,105.97) = 4.48$, $p = .037$), Neuroticism ($F(1,105.97) = 9.1$, $p = .003$), and Extraversion ($F(1,105.45) = 4.2$, $p = .43$). Larger error rates were observed for correct sentences, and linear trends indicated that higher levels of Neuroticism corresponded to larger error rates and vice versa, while the opposite pattern was observed for Extraversion. Other

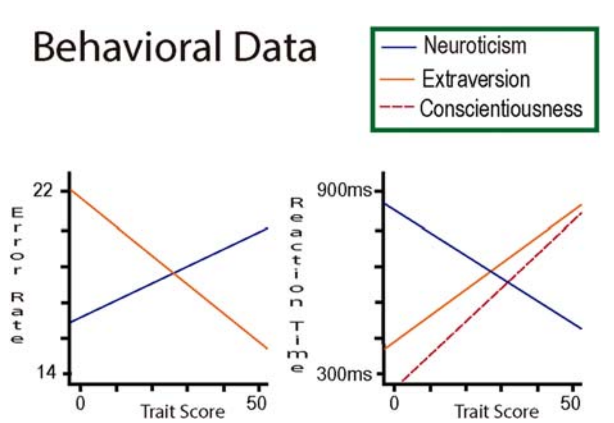

Figure 3. Estimated linear trends for Neuroticism, Extraversion, and Conscientiousness on error rates and reaction times.

significant findings were not observed (All Fs < 3.1, ps > 0.8). Finally, in regard to reaction times, significant differences were observed for Neuroticism (F(1,99.91) = 9.4, p = .003), Extraversion (F(1,99.52) = 4.2, p = .006) and Conscientiousness (F(1,105.97) = 6.7, p = .011). Specifically, higher scores of Neuroticisms and Conscientiousness corresponded to longer reaction times and vice versa, while for Extraversion the opposite pattern appeared (Figure 3).

Skin conductance data

Normalised skin conductance data was analysed by means of a repeated measures Correctness by Social Presence ANOVA with all five personality traits as intersubject factors, yielding a virtually significant Social Presence Condition by Extraversion interaction (F(1,9) = 4.91, p = .054, η_p^2 = .353, θ = .507). *Post hoc* pairwise comparisons revealed that, indeed, participants that scored lower in Extraversion showed significantly higher arousal in the social condition (M = 2.04, SE = .323) than when alone (M −.04, SE = .32; Δ = 2.08, p = .013). Interestingly, this analysis also revealed a significant Social Presence Condition by Openness interaction (F(1,9) = 5.37, p = .046, η_p^2 = .374, θ = .543) which pairwise comparisons indicated stemmed from a significant difference for participants higher in Openness between the alone (M −.051, SE = .290) and social presence conditions (M = 2.051, SE = .290; Δ = −2.101, p = .006). In other words, it seems that both less extraverted participants and more open participants showed higher measures of skin conductance in social presence than when alone. Linear models analyses did not yield significant effects for any factor or interaction except for correctness (F(1,104.47) = 4.16, p = .044), where larger skin conductance levels were observed for correct sentences than for incorrect sentences.

EEG data

After removing incorrect trials and bad epochs, an average of 29.59 and 37.38 (out of 50) correctly answered trials were included in the data analyses for correct and syntactic anomaly sentences, respectively. As a consequence of the larger error rates produced for correct sentences than for incorrect sentences, the percentage of epochs included in the analyses was smaller for correct than for incorrect trials (t(28) = 4.80, p < .001).

Repeated measures ANOVAs were performed at two separate time windows, namely, 400–500 ms and 600–800 ms. The ANOVAs included four within-subjects factors (Hemisphere (Left, Right), Region (Anterior, Central, Posterior), Correctness (Correct, Incorrect), Social Presence condition (Alone, Social Presence) and five between-subject factors (personality traits Extraversion, Neuroticism, Agreeableness, Openness, and Conscientiousness)). Linear mixed models were calculated using the same time windows and ROIS (that is, introducing Hemisphere, Region, Presence, and Correctness as repeated factors, and the personality traits as covariates). Given the large number of results provided by these analyses, linear mixed models results can be found in Appendices 1 and 2, while only the significant results of the repeated ANOVA analyses are reported here.

Overall, the main repeated measures ANOVA including all personality traits at the 400–500 ms window yielded statistically significant Correctness effects, indicating the LAN component was indeed elicited during this window (F(1,28) = 6.45, p = .032, η_p^2 = .417, θ = .620). The same analyses in the 600–800 ms interval revealed a significant syntactic P600 (F(1,28) = 43.87, p < .001, η_p^2 = .830, θ = 1.00). Interactions between Social Presence condition, Correctness and Region were also observed at 400–500 ms and 600–800 ms windows (F(2,56) = 6.95, p = .023, η_p^2 = .436, θ = .677; F(2,56) = 6.12, p = .022, η_p^2 = .405, θ = .701, respectively). In addition, multicollinearity analyses revealed that all VIF values were between 1 and 10 (1.03 < VFs < 1.34), indicating that the no multicollinearity assumption needed to calculate ANOVAS was met. Furthermore, correlation calculations among personality traits did not reveal any significant correlations between traits (all rs < .23 ps > .05) except between Neuroticism and Extraversion (r = −.45, p = .013).

In line with the main aim of this study, interactions between personality traits, correctness and/or presence will be discussed below in detail. In this regard, both the linear model analyses and repeated measures ANOVA yielded significant correctness interactions with Conscientiousness, Extraversion, and Agreeableness personality traits. The linear model analyses also revealed significant effects of personality traits, either for the alone condition or interacting with hemisphere or/and region (Appendices 1 and 2). However, given that they are outside of the scope of the present article, they are neither reported nor discussed below.

Extraversion data

Repeated ANOVA analyses resulted in a statistically significant Correctness x Social Presence × Extraversion interaction in the 400–500 ms window (F(1,9) = 5.60, p = .042, η_p^2 = .384, θ = .560), indicating that level of Extraversion may interact with social contexts when triggering the LAN effect. Post-hoc pairwise comparisons highlighted that those participants lower in Extraversion showed a significantly more negative amplitude of the LAN, as syntactic sentences showed a more negative amplitude in the alone condition (M −1.13 μV, SE = .38) compared to the social presence condition (M −.322 μV, SE = .35; Δ = −.803 μV, $p < .05$), whereas correct sentence amplitude was essentially unchanged. Furthermore, visual inspection suggested that component distribution differed between Extraversion levels and according to social condition. Specifically, in the social presence condition these participants showed a weaker and more posterior component in comparison to the alone condition. After subtracting correct sentence amplitude from syntactically

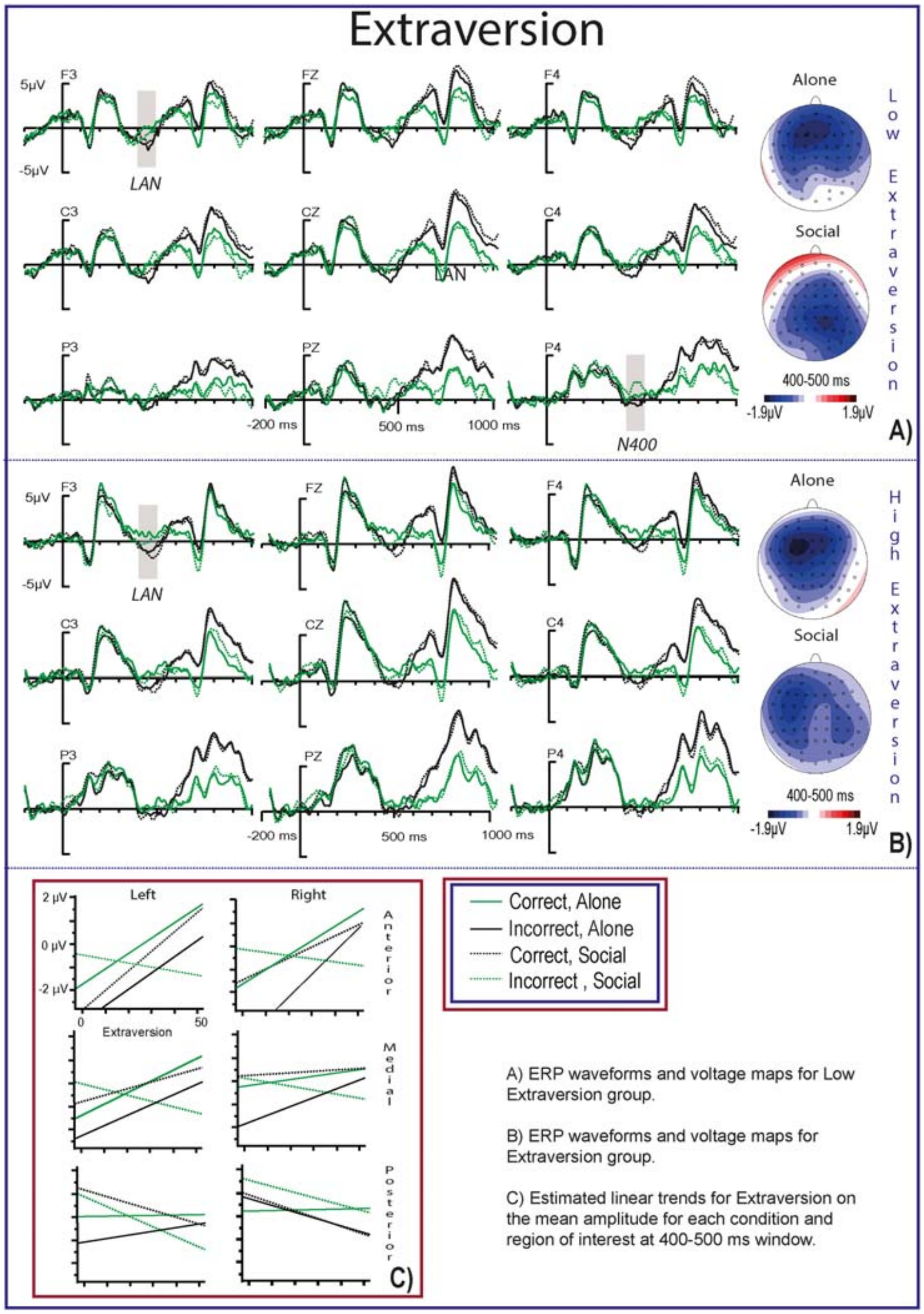

Figure 4. ERPs to syntactically correct and incorrect sentences alone and in social presence, for participants with lower (A) and higher (B) scores in Extraversion. Difference maps (incorrect minus correct) of the LAN in the analysed time window in the alone condition and social condition, as well as the ERP waveforms at selected electrodes during the alone and social conditions, can be seen for less extraverted participants (A) and more extraverted participants (B). Estimated linear trends for Extraversion on the mean amplitude for each condition and region of interest at 400–500 ms windows (C).

incorrect sentence amplitudes, the remaining data was analysed by means of a Hemisphere × Region × Social Presence ANOVA with Extraversion specifically as an intersubject factor. This analysis revealed a Region × Social Presence interaction ($F(2,54) = 4.10$, $p = .048$, $\eta_p^2 = .132$, $\theta = .527$), indicating that social presence impacted the distribution of the LAN regardless of level of Extraversion, leading specifically to the more frontal LAN effects observed in the alone condition, and more a posterior component resembling an N400 in the social condition (Figure 4).

Linear Model analyses at 400–500 ms found significant main effect of Extraversion and for the interaction of Social Presence by Extraversion (ps < .05) (Appendix 1). Linear trends revealed that for the social condition, smaller values in Extraversion corresponded to more negative voltage while larger values corresponded to more positive voltage, and vice versa for the alone condition (Figure 4). For the 600–800 ms window neither Linear models nor repeated measure analyses yielded significant results.

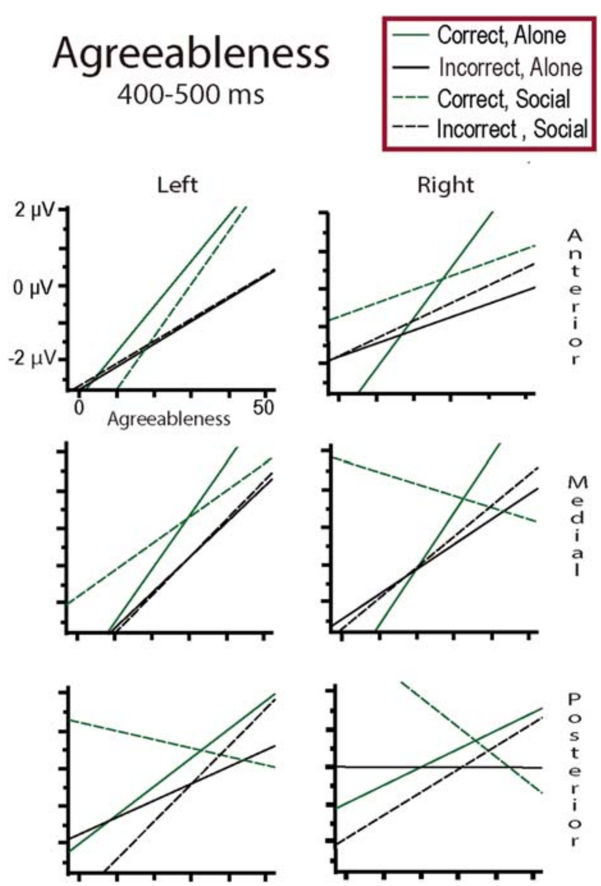

Figure 5. Estimated linear trends for Agreeableness on the mean amplitude for each condition and region of interest at 400–500 ms windows.

Agreeableness data

Although the repeated measures ANOVA at the 400–500 ms window did not indicate any significant effects, according to the linear model analyses there was indeed a significant Presence by Correctness by Agreeableness interaction ($p < .05$). Linear trends revealed a complex interaction (Figure 5). Within the social condition, they indicated a negative component for low Agreeableness, while it appeared a positive one for high Agreeableness at all ROIS except for the left anterior region. In the alone condition, this pattern seemed to appear only at posterior regions. At the 600–800 ms window neither the linear model analyses nor the repeated ANOVA yielded any significant differences.

Conscientiousness data

The main repeated measures ANOVA revealed a trend towards a Correctness by Conscientiousness interaction ($F(1,9) = 4.19$, $p = .073$, $\eta_p^2 = .317$, $\theta = .447$). Given the purpose of the present study and linear models' significant results, we decided to calculate planned post-hoc pairwise comparisons in this window, analysing high and low Conscientiousness group separately. They revealed that, remarkably, there was a significant main effect of Correctness regardless of the region in 400–500 ms window for those higher in Conscientiousness ($\Delta = -1.311$ µV, $p = .015$), but not for those lower in Conscientiousness ($\Delta = -.420$, $p = .380$). Nonetheless, visual inspection still showed an apparent LAN component for lower Conscientiousness, though restricted to frontal electrodes (F3, F1, Fz, F2, and F4). Indeed, ANOVA analyses exclusively at these five anterior electrodes yielded a significant correctness effect ($F(1,13) = 4.75$, $p = .048$, $\eta_p^2 = .268$, $\theta = .523$). Overall, although not a highly robust finding, the LAN appeared significantly reduced in participants with lower Conscientiousness. Similarly, In the 400–500 ms interval the linear model analyses yielded significant results for Correctness by Conscientiousness and a region by Conscientiousness interactions (all ps < .05) (Appendix 1). Linear tendencies showed that, especially in anterior regions, the component amplitude tended to be smaller for low Conscientiousness than for high Conscientiousness (Figure 6).

The repeated ANOVA yielded a significant Region by Correctness by Conscientiousness interaction ($F(2,18) = 4.65$, $p = .048$, $\eta_p^2 = .341$, $\theta = .549$). Post-hoc pairwise analyses revealed that the P600 amplitude (that is, the difference between incorrect and correct waves) was significantly larger for participants lower in Conscientiousness ($\Delta = 1.59$, $p = .027$) than those higher in this trait.

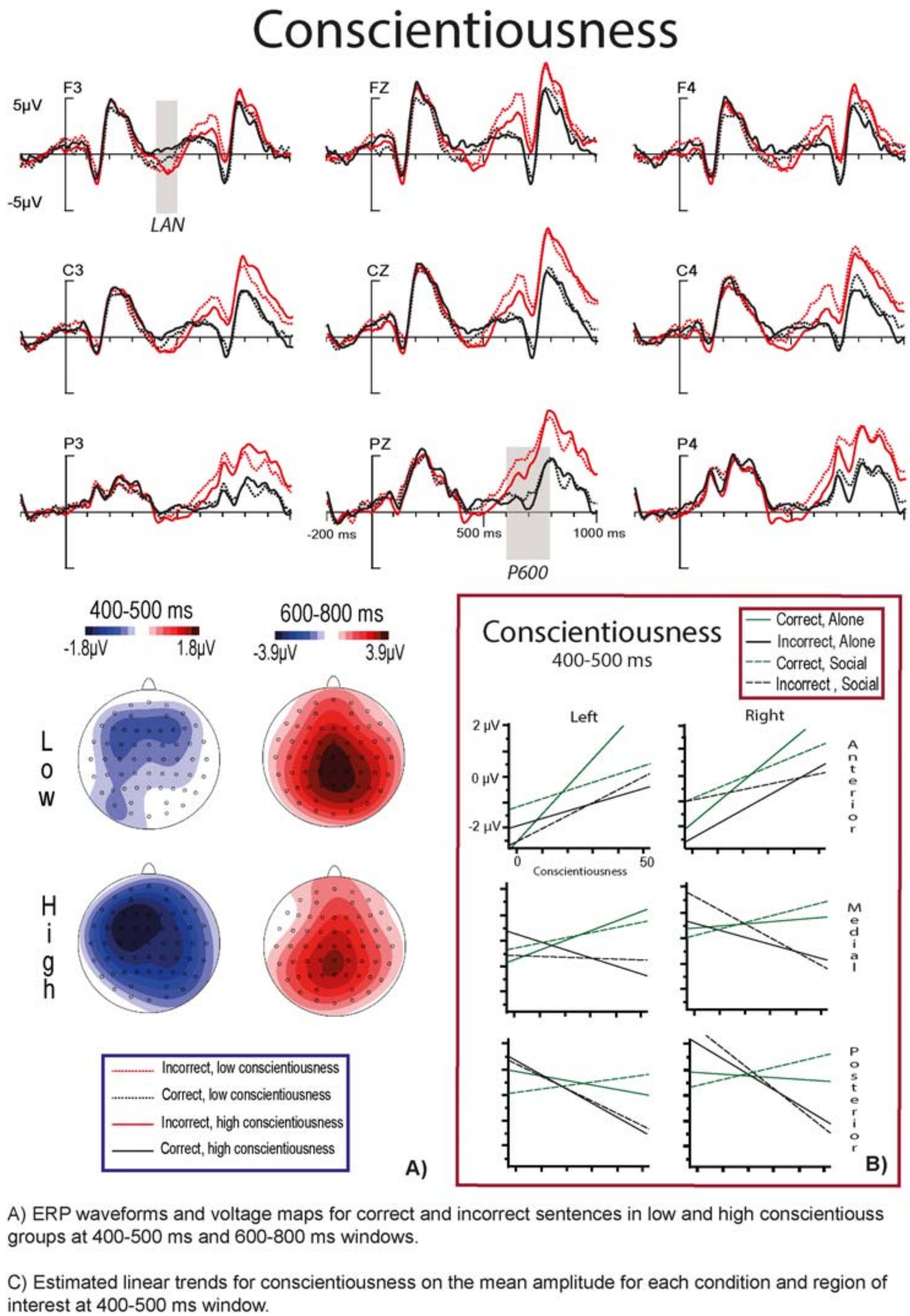

Figure 6. (A) ERP to syntactically correct and incorrect sentences collapsed across social presence conditions, for participants with lower and higher scores in Conscientiousness. Top: ERP waveforms at selected electrodes for all participants. Bottom: Difference maps (incorrect minus correct) of the LAN and P600 in the analysed time windows for participants lower (top row) and higher (bottom row) in Conscientiousness. (B) Estimated linear trends for Conscientiousness based on the mean amplitude for each condition and region of interest at 400–500 ms windows.

In contrast, linear model analyses did not find significant differences at the P600 window (600–800 ms).

Discussion

The present study aimed to investigate how the dimensions of personality postulated by the Big Five model modulate syntax processing in the presence or absence of a confederate. As such, following a summary of the overall results, we will focus this discussion on traits by correctness effects.

In regard to the question of whether personality interacts with behavioural measures, a linear mixed model of behavioural data indicated that whereas higher

Neuroticism was related to more incorrect answers and longer reaction times, higher Extraversion levels was associated with smaller error rates and shorter reaction times. In addition, higher levels of Conscientiousness were associated with longer reaction times. Interestingly, in regard to psychophysiological measures, we found that lower Extraversion and higher Openness groups showed significantly higher arousal in the social condition than when alone.

As for the ERP results, findings showed that the traits Extraversion, Conscientiousness and Agreeableness seemed to have interacted in syntactic processing modulations, though to different degrees. The high Extraversion group triggered a clear LAN component both in social and alone conditions, although it was only statistically significant in the social condition. However, the low Extraversion group in the social condition triggered a weaker and more posterior negative component, resembling an N400 component (main component activity is around P2 and CP2 electrodes), compared to when alone (main component activity is around F3 electrode). The low Conscientiousness group triggered a weaker and more restricted LAN and a larger P600 than those higher in Conscientiousness, and moreover, linear model analyses indicated that lower levels of Conscientiousness were associated with a smaller LAN component. Lastly, linear model analyses also revealed an interaction between social presence conditions, sentence correctness and Agreeableness. However, linear trends suggested a complex relationship between these variables.

The behavioural data seem to indicate that personality traits may affect decision-making and error detection, in that higher levels of Neuroticism were linked not only with more incorrect answers (higher error rates), but also with taking longer to make a decision about the correctness of the sentence. Along these lines, high levels of Neuroticism have been previously related to poor decision-making and low self-esteem (Denburg et al., 2009; Lauriola & Levin, 2009; Uziel, 2010). One explanation might be that those participants more prone to feelings of anxiety or nervousness may experience greater distress when observing morphosyntactic anomalies, resulting in a poorer performance. This interpretation is in line with Hubert and Järvikivi (Hubert, 2020; Hubert & Järvikivi, 2019, 24-27 july). dark forces in language comprehension: the case of neuroticism and disgust in a pupillometry study proceedings of the 41st annual meeting of the cognitive science society, montreal, qc) findings, where they observed that greater pupil dilatation was associated with higher Neuroticism levels and vice versa in an auditory language comprehension task including morphosyntactic anomalies. The interactions between both Extraversion and Conscientiousness with behavioural effects will be discussed below in relation with ERP findings.

Interestingly, the ERP interactions between Extraversion, syntactic processing, and social condition, were partially in line with behavioural and skin conductance findings. The pattern of larger error rates and longer reaction times associated with lower Extraversion is particularly noteworthy, given that the low Extraversion group also presented higher skin conductance levels and, remarkably, triggered a weaker and more positive early syntactic component in the social condition. Judging by the positive correlation between Extraversion and high self-esteem that some authors have noted (Robins et al., 2009; Uziel, 2010), it is plausible that introversion may potentially be related to lower self-esteem, in which case introverts might have a more aversive reaction to social presence. Indeed, under the assumption that arousal reflects alertness or readiness in response to the uncertainty that the other person poses, as is posited by the monitoring theory of social facilitation (Guerin, 1993; Guerin & Innes, 1982), this increased arousal may indicate increased need to monitor for potential threats. Moreover, if introverted participants tended to be more distracted or affected by the confederate's presence, perhaps this led to a starker division of attentional resources between the social presence and the syntactic error, resulting in larger error rates, reaction times and a weaker syntactic component. This might also explain why the distribution of the LAN in the social presence condition looks more like an N400 distribution for introverts. It has been proposed that this type of N400-like distribution in response to syntactic anomalies reflects "the use of alternative strategies to solve these anomalies" (Bornkessel-Schlesewsky et al., 2011), likely appearing in response to syntactic information when lexico-semantic information processing is required (Molinaro et al., 2011). The more lexico-semantic information is processed, the more N400-like the distribution of the negativity to syntactic agreement violations will be (Bornkessel-Schlesewsky et al., 2011; Mancini et al., 2011; Molinaro et al., 2015). Accordingly, the change in the processing strategy triggered by social presence in introverts could be the result of a more heuristic-like or associative processing style, which does not take all available information into account but rather relies on previous knowledge and shortcuts. The heuristic processing style is typically more characteristic of lexico-semantics operations instead of the algorithmic, highly detailed, systematic and rule-based strategy expected for morphosyntactic violations (Hinchcliffe et al., 2020;

Martin-Loeches et al., 2009; Vissers et al., 2013). In a previous study, an N400-like component instead of a LAN was observed when the participant was accompanied by a confederate while judging syntactic anomalies (Hinchcliffe et al., 2020). Our results might indicate that introverts could be the main contributors to the shift observed in the component's topography. Furthermore, behavioural results show less accuracy and longer reaction times associated with lower levels of Extraversion. Accordingly, the heuristic strategies used by introverts, which in other contexts might be an index of creativity and flexibility (Kutas & Federmeier, 2011; Zhou et al., 2018), seem to be less efficient in detecting morphosyntactic anomalies given the intrinsic nature of the task, requiring a detailed, more systematic approach (Martin-Loeches et al., 2009; Vissers et al., 2013).

In regard to Agreeableness, linear model analyses and trends suggested a complex interaction between this trait with correctness and presence. Whereas lower levels of Agreeableness seemed to correspond to a more negative component, larger values seemed to trigger a positive component for all ROIS except for the left anterior one. In the alone condition, this pattern seem to appear only in posterior regions, whereas in the social condition it occurred in almost all regions of interest. However, the results are ultimately too complex to draw a clear conclusion as to how Agreeableness might affect language comprehension in the social condition. In addition, ANOVA analyses using high and low Agreeableness groups did not yield neither tendencies nor statistically significant results. Thus, in order to confirm these results, future research should include more subjects or maybe a design focused on this trait.

Perhaps the most notable findings from the present study were that Conscientiousness appeared involved in aspects of early and late syntactic processing. Although the results of the overall ANOVA have not been as statistically robust as in the post-hoc including just Conscientiousness, a clear pattern arises when also taking into account the model analyses and topographic maps (See Figure 6). Those lower in Conscientiousness revealed smaller LAN and greater P600 components, whereas those higher in Conscientiousness presented a more prominent LAN and a smaller P600 component. This pattern has been previously described, where good comprehenders (i.e. participants with better working memory capacities) showed a larger LAN/ reduced P600 in comparison to bad comprehenders (individuals with lower working memory capacity) (Coulson & Kutas, 2001; King & Kutas, 1995; Tanner & Van Hell, 2014). The same pattern appears when emotional information precedes a sentence containing a morphosyntatic violation, compared to neutral information (Espuny et al., 2018). The increased LAN / reduced P600 pattern is therefore generally interpreted as a result of a more efficient processing of syntactic information. In addition, the present study found that the higher the level of Conscientiousness, the longer the reaction times. However, since this trait did not correspond with larger error rates, as occurred in the case of Neuroticism, it might indicate a more thorough processing, resulting in a larger syntactic component.

High Conscientiousness has been associated with self-discipline, self-control, competitiveness and being remarkably rule-abiding (Jackson & Roberts, 2017; Stock & Beste, 2015). Syntactic processing has been considered as mainly algorithmic and rule-based, "following a finite list of well-defined instructions about how lexical elements combine to form phrases and sentences" (Friederici & Weissenborn, 2007; Martin-Loeches et al., 2009). The rule-abiding tendency characteristic of high Conscientiousness might favour syntactic processing, making it more thorough and efficient, as occurs in good comprehenders. An alternative/complementary explanation might be that Conscientiousness was associated with superior executive functioning, particularly as this trait seems to be related to the attention shifting or switching component of executive function (Fleming et al., 2016), which might also contribute to the increase of performance for high Conscientiousness observed in the present study.

Together, the present data indicate influences of personality on language comprehension. Nonetheless, several limitations should be addressed in future research. Although the sample size met the average requirements for neuroimaging studies, in order to get an even fuller picture of individual differences future studies should include at least the recommended amount of 40 participants (Yarkoni, 2010). In addition, behavioural prescreening can achieve a power boost comparable to larger sample sizes without inflating the false positive rate (de Haas, 2018). As suggested above, creating groups of subjects focusing in one trait by using pre-screening might have several statistical and methodological advantages. Additionally, the majority of participants were females favouring sample homogeneity, but further research should explore possible gender effects. Regardless of the limitation of the sample, our study fulfils many of the recommendations made by Yarkoni and Braver (2020), such as homogeneous sample, the use of a task known to produce consistent changes in ERP with performance levels above 80 of accuracy, and behavioural data measurements. In addition, effect size and power calculations were provided when possible. Therefore, regardless of its size limitations, this study may provide a good initial starting point for future research on how extra-linguistic information like personality and social presence affect language comprehension.

Conclusion

Personality has been noted as a potential mediator of social presence effects as well as of various cognitive processes. The present study aimed to measure the relationship between personality, as measured by the NEO-FFI, and language ERPs as participants responded to syntactic anomalies, once alone and once in the presence of a confederate. While it must be considered that a larger sample of participants might increase robustness of the findings, the results indicate that Extraversion, Conscientiousness and likely also Agreeableness may have intervened to some degree in syntactic processing. Additionally, future studies could further investigate this question by choosing larger samples and/or prescreened samples that are specifically high, medium and low in each trait. On the other hand, the results of the present study imply that even in a sample with a relatively normal distribution of scores on each trait, there still seem to be effects of personality differences on components of syntactic language comprehension. Findings of this type indicate that the brain's language processing system consider extralinguistic factors as relevant information, and that this is the case even for syntactic processing, traditionally considered as encapsulated (Fodor, 1983; Hauser et al., 2002). Importantly, our results highlight the utility of considering personality traits and social context as relevant factors modulating language comprehension, adding to recent and yet incomplete evidence in this respect.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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