How Clinical Decision Tasks Modulate Emotional Related EEG Responses in Nursing Students

Yurena Morera[1,2], Naira Delgado[1,2], Enrique García-Marco[2,3], Adolfo M. García[4,5,6], Manuel de Vega[1,2], Lasana T. Harris[7]

[1] Departamento de Psicología Cognitiva, Social y Organizacional. Universidad de La Laguna, Islas Canarias, Spain

[2] Instituto Universitario de Neurociencia (IUNE). Universidad de La Laguna, Islas Canarias, Spain

[3] Departamento de Psicología Clínica y Experimental, Universidad de Huelva, Huelva, Spain

[4] Cognitive Neuroscience Center (CNC), Universidad de San Andrés, Buenos Aires, Argentina

[5] Global Brain Health Institute (GBHI), University of California San Francisco (UCSF), San Francisco, USA

[6] Departamento de Lingüística y Literatura, Facultad de Humanidades, Universidad de Santiago de Chile, Santiago, Chile

[7] University College London, UK

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Corresponding author: Enrique García-Marco, Avenida de las Fuerzas Armadas s/n, 21007 Huelva, Spain. Email: enrique.garcia@dpces.uhu.es

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Abstract

Healthcare professionals play a vital role in conveying sensitive information as patients undergo stressful, demanding situations. However, the underlying neurocognitive dynamics in routine clinical tasks remain underexplored, creating gaps in healthcare research and social cognition models. Here, we examined whether the type of clinical task may differentially affect the emotional processing of nursing students in response to the emotional reactions of patients. In a within-subjects design, 40 nursing students read clinical cases prompting them to make procedural decisions or to respond to a patient with a proper communicative decision. Afterward, participants read sentences about patients' emotional states; some semantically consistent and others inconsistent along with filler sentences. EEG recordings towards critical words (emotional stimuli) were used to capture ERP indices of emotional salience (EPN), attentional engagement (LPP) and semantic integration (N400). Results showed that the procedural decision task elicited larger EPN amplitudes, reflecting pre-attentive categorization of emotional stimuli. The communicative decision task elicited larger LPP components associated with later elaborative processing. Additionally, the classical N400 effect elicited by semantically inconsistent sentences was found. The psychophysiological measures were tied by self-report measures indexing the difficulty of the task. These results suggest that the requirements of clinical tasks modulate emotional-related EEG responses.

Keywords: Healthcare professionals; EEG; Processing emotional information; Emotional regulation strategies

1. Introduction

Healthcare professionals are required to make informed decisions that carry significant consequences for patients. These choices often have to be made despite limited information, resources, and expertise, even having an expectation that these decisions are made meticulously and accurately (Masic, 2022). In clinical decision-making, emotions play a crucial role, both reducing the likelihood of committing diagnostic errors (Liu, 2022) and facilitating the emotion regulation of healthcare professionals in high-demand and high-uncertainty situations. Nurses are expected to optimize their specialized knowledge when making decisions (Gillespie & Peterson, 2009), and they must also actively apply self-regulation strategies to maintain personal control and balance, while maintaining professional efficiency in highly emotional demanding contexts (Gleichgerrcht & Decety, 2012). Such physician-patient interactions tap on crucial socio-cognitive mechanisms that involve attentional, emotional, and semantic operations (Dolcos *et al.*, 2011). Yet very little is known about the neurophysiological signatures of the socio-cognitive mechanisms required for technical diagnostic or procedural decisions and communicating sensitive information to patients. Specifically, the aim of this research is to explore whether technical decisions and communication tasks produce different effects on how emotional information from patients is processed and integrated.

Emotional Processing in Clinical Decision-Making

Decision-making is pervasive in clinical practice. For instance, health professionals are constantly collecting information, assessing test results, establishing treatment objectives, or providing advice, referrals, admissions, or discharges for patients (Ofstad et al., 2018). Several factors like complexity or task familiarity influence the decision-making process. Besides, individuals possess a finite capacity for processing information, making it progressively challenging to fully grasp a decision situation and the extent of potential actions (Swaby et al., 2022). Introducing further complexity to these processes, clinical decisions are often made in contexts that are emotionally challenging. Healthcare professionals spontaneously activate emotional regulation strategies during patient interactions, improving performance and enhancing cognitive processes associated with attention, semantic integration, and stimulus encoding (Jensen et al., 2014).

Theoretical approaches postulate that task demands shape healthcare professionals' perception and interaction with patients, influencing the processing of emotional information and employing different emotion regulation strategies (Haque & Waytz, 2012; Cameron et al., 2019). As a result, it is expected that the way healthcare professionals perceive and interact with patients could depend on the task demands they have to do (Haque & Waytz, 2012; Harris, 2017). For example, engaging in social cognition processes such as determining the patients' feelings and concerns can be functional to a surgeon while interacting with their patient before or after the surgery, but maladaptive when the same physician operates on their anesthetized patient (Harris, 2017; Moser *et al.*, 2010). Following this reasoning, the type of task in which healthcare professionals are involved could determine how the patients' emotional information is processed—depending on whether it is perceived as relevant or not to the clinical task—through different forms of emotion regulation strategies that may improve performance and reduce emotional costs (Cameron *et al.*, 2019). Despite the theoretical advancements and practical relevance of this question, empirical studies addressing it are scarce and primarily reliant on self-reported measures. In an attempt to address this issue, the present research sought to extend evidence by testing whether the type of task in which healthcare professionals are involved determines how they access and process patients' emotional information. We adopt a neurocognitive approach as it enables the use of no-invasive measures to explore intricate phenomena like complex social interactions in healthcare and clinical decision-making. In this vein, the use of neuroscience methods helps us to disentangle cognitive mechanisms involved in the processing of emotional stimuli without interrupting or affecting the cognitive processes involved.

Neurocognitive Traces of Emotional Processing in Healthcare Professionals

Previous research shows brain differences in the way that healthcare professionals process emotional information compared to non-medical controls. In a study measuring ERPs, Decety *et al.* (2010) presented visual stimuli depicting body parts pricked by a needle (painful) or a cotton swab (non-painful) to physicians and matched controls. They found an early frontal N110 differentiation between pain and no pain condition (as an index of negative arousal), as well as a late central-parietal P300 component that were modulated by medical expertise. Concretely, both components were larger in the control participants while both painful and non-painful stimuli elicited similar responses in the physicians, showing that healthcare professionals regulate both the early ERP component associated with spontaneous emotional responses, and the middle ERP component related to the cognitive evaluation of others’ pain (Decety *et al.*, 2010). Additionally, Cheng *et al.* (2007) found greater activation in areas involved in executive control, self-regulation, emotional regulation, and social cognition (i.e., medial and dorsolateral prefrontal cortices and the temporo-parietal junction) in physicians compare to non-physicians. These findings suggest that healthcare professionals can *down-regulate* the relatively spontaneous brain response to pain, better regulating emotional responses than control groups (Haque & Waytz, 2012; Jensen *et al.*, 2014). In sum, the present data show that physicians spontaneously activate emotional regulation strategies while interacting with patients' pain. The regulatory mechanisms involved in the processing of the patient's emotions could operate during different stages to improve performance in doctor-patient interaction; including spontaneous, early, effortless processes associated with attentional orientation and semantic integration, to more controlled, late, cognitively demanding processes associated with more elaborative re-categorization and stimulus encoding.

Study rationale

Despite the theoretical interest in healthcare professionals' emotional responses, no study focuses on how the type of clinical task could modulate brain activity associated with the processing of emotional stimuli. To solve this gap, we designed the present study to explore whether brain markers associated with the processing of emotional information are modulated differently by two highly relevant tasks in clinical practice:

1) *A procedural decision task*, focused on technical decisions about treatment;

2) *A communicative decision task*, focused on communicating sensitive information to patients.

The reason to choose these two main types of clinical tasks is that, although clinical tasks can be classified in different ways, "Assess" and "Communicate" always appear among the main ones (Stein et al., 2009). Importantly, these two types of tasks require different skills, with an emphasis in social cognition and empathy in the communicative task. Therefore, by studying both types of tasks we can compare the automatic response and dissociate regulation of emotional responses

In the experimental task, we requested nursing students to read emotion-laden clinical vignettes. They were tasked with communicating information or making a non-emotional procedural decision. Alongside, they were presented with semantically congruent sentences about patients' emotional states and semantically inconsistent sentences, This manipulation allows us to take a measure of semantic integration by means of the expected classical effect in N400. We focused on three ERP components that can be singled out as critical targets to capture relevant dynamics of task-related processing: The early posterior negativity (EPN), to measure indices of emotional salience, the late positive potential (LPP) to capture indices of attentional engagement, and the N400 as an index of semantic integration. Finally, we examined correlations between significant event-related potential (ERP) modulations and measures of cognitive effort and mental state inferences. This way, we aimed to elucidate the distinct neurocognitive traces of clinical task demands.

The EPN is a mid-latency component (200-400 milliseconds [ms]) characterized by increased occipital-temporal negativity that responds differentially to emotional stimuli compared to neutral stimuli (Junghofer *et al.*, 2001; Palazova *et al.*, 2013), reflecting initial semantic categorization and attention capturing by emotional stimuli (León *et al.*, 2010; Schacht & Sommer, 2009b; Palazova *et al.*, 2013). Some researchers argue that it is task independent (e.g., Citron, 2012), while other evidence shows EPN amplitude differences for the same stimulus under different emotional contexts (Aldunate *et al.*, 2018). The LPP is a midline positive-going ERP component (500-2000 ms) that reflects a sustained increase in brain activity in response to emotional compared to neutral stimuli (Cuthbert *et al.*, 2000; Foti & Hajcak, 2008; Hajcak *et al.*, 2010; Schupp *et al.*, 2000; Schupp *et al.*, 2004). It is sensitive to the preceding emotional context (Foti & Hajcak, 2008; Ibanez *et al.*, 2012; Schupp *et al.*, 2006; Schupp *et al.*, 2007); and it is observed to be larger for contextual and pragmatic expectation inconsistencies compared to consistent expectations (Baetens *et al.*, 2011; Bartholow *et al.*, 2001;

Foucart *et al.*, 2015) suggesting it is related to re-evaluation and re-integration processes. Finally, LPP is used to measure successful engagement of regulatory processes (Hajcak & Nieuwenhuis, 2006; Krendl *et al.*, 2017; MacNamara *et al.*, 2011). Note, however, that the mentioned ERPs measures are not uniquely related to emotional brain processes. For instance, there is ample support that the LPP is also modulated by non-affective stimuli that require effortful cognitive processing (Matsuda & Nittono, 2015), being larger for semantic-meaning inconsistencies (Baetens *et al.*, 2011; Foucart *et al.*, 2015; Van Berkum *et al.*, 2009) compared to consistent meaning, suggesting it is related to re-evaluation and re-integration processes. Another relevant component is the N400, a midline negative component (300-500 ms.) that reflects integration of semantic information (Kutas, 1997; Kutas & Hillyard, 1980, Kutas & Federmeier, 2011), and is modulated by a variety of factors, such as semantic priming, context, and predictability (Lau *et al.*, 2008).

In line with previous studies, we expected:

(1) An early negativity (EPN) in response to the arousal of the presented emotional stimuli. Results on the influence of previous context in this ERP component are controversial. If a significant type of task effect is obtained, there are two possibilities: That the EPN will be larger in the procedural decision task compared to the communicative decision task or *vice versa*, depending on which of the two contexts emotional information would be more salient for the participants. In any case, these results would support –or not– the idea of a relatively rapid impact of the experimental tasks in the processing of emotional words.

(2) We also hypothesized that the clinical task manipulation would modulate the latency amplitude of the LPP component. In line with previous literature, we expected that the LPP for emotional words in the context of the communicative decision task would be

larger –because emotional information in this context would involve more elaborative and evaluative processes– compared to emotional words in the context of the procedural decision task.

(3) Finally, we expect two additional main effects associated with the brain responses modulated by the semantic consistency/inconsistency of the critical words: (a) A larger N400 for inconsistent than for consistent critical words, reflecting greater difficulties in integration of semantic information; and (b) a larger LPP for inconsistent than consistent critical words, indexing sustained processing of those stimulus.

2. Method

2.1. Participants

The study involved 40 third- and fourth-year nursing students (36 females; mean age 21.9 years, range 18-39) at University of La Laguna. We used G*Power 3.1.9.6 (Erdfelder *et al.*, 1996) to determine the required sample size for a 2x2 Repeated Measures ANOVA. Using a medium effect size of $f = 0.25$, a significance level (alpha) of 0.05, and a power of 0.95, the analysis indicated that a total sample size of 36 participants would be necessary to detect the anticipated effects. Our actual sample size (n = 40) reached a power of 0.97. According to the academic itinerary, at this time nursing students have completed at least 390 hours of clinical practice; rotated through various hospital departments and directly contacted different kinds of patients. They were neurologically healthy, right-handed native Spanish speakers and had normal or corrected-to-normal eyesight. The study was approved by the Ethics Committee of the University of La Laguna (Register CEIBA 2021-0443). All participants gave written informed consent according to the Declaration of Helsinki and received 15 euros for their participation.

2.2. Experimental design and materials

Experimental design

We employed a 2 x 2 repeated-measures experimental design, involving Task (procedural decision and communicative decision) and Semantic consistency sentence (consistent and inconsistent).

Experimental blocks and structure of an experimental trial

During each trial, participants read short clinical case descriptions. Then, they either made a technical decision about a treatment for a patient (procedural decision task) or decided on how to communicate information to a patient (communicative decision task). Following this task, two types of sentences with emotional content were presented to ascertain the understanding of the conveyed information:

1) Sentences with information that was semantically consistent with the clinical case exposed in each of the trials (e. g. *Peter feels distressed*);

2) Sentences with information that was semantically inconsistent with the clinical case (e. g. *Peter feels whipped*).

Importantly, the participants just read the sentences with emotional content to assure comprehension and were not asked for any explicit emotional evaluation. The fact that the task manipulation took place *before* subjects processed the critical sentences, and that the critical sentences were the same in both experimental conditions, allows us to analyze how two different tasks with different clinical goals could influence the brain response to emotional stimuli. Specifically, ERP data were collected to tap the processing of emotional words in the critical sentences.

Clinical cases

The stimuli were 30 short clinical cases in Spanish, crafted by nursing experts from field-specific materials (see Appendix A in Supplementary materials). These cases were split evenly between the two tasks. A normative study with another 32 nursing students, based on 0-to-100 rating scales, showed that all cases were highly coherent (to what extent the case maintained a logic structure; procedural decision: $M = 76.63$, $SD = 5.97$; communicative decision: $M = 78.57$, $SD = 4.47$; $t\ (14) = .518$, $p = .612$) and moderate in difficulty (to what extent the decision was difficult; procedural decision: $M = 48.07$, $SD = 5.12$; communicative decision: $M = 46.07$, $SD = 6.74$; $t\ (14) = .883$, $p = .392$) and seriousness (to what extent the case can be considered severe; procedural decision: $M = 57.75$, $SD = 8.22$; communicative decision: $M = 62.29$, $SD = 3.99$; $t\ (14) = .986$, $p = .341$). Neither variable showed significant differences between procedural decision and communicative decision cases. Additionally, both sets were matched for overall number of words and number of nouns, adjectives, and adverbs (see Table 1 in Appendix A). They were also matched in terms of gender and age, with the latter encompassing a wide range (from 8 to 82 years old).

Procedural decision task vs. communicative decision task

Experimental conditions were created through the design of two different tasks using a three-alternative choice question after reading each clinical case. In the procedural decision task, they selected the most adequate medical procedure. In the communicative decision task, they opted for the most adequate response to a patient's situation. All items in each condition involved an optimal response, validated as such by a normative study with 32 nursing students who did not participate in the main experiment (optimal options were identified as such in 80.16% of responses) (in Appendix A is included an example of the three alternative choice question in both experimental tasks).

Continuation and critical sentences

Each clinical case was followed by a continuation sentence (e.g., *arriving at the hospital Pedro showed signs of pain*), aimed to connect the clinical cases and the critical sentences, maintaining the emotional tone of the experimental context. Out of the six critical sentences, two of were semantically consistent with the clinical case, two were inconsistent; and two neutrals (non-emotional), which were considered filler. Examples of continuation sentences, critical sentences and filler sentences are shown in Appendix B, Table 2). Semantic consistent and inconsistent words were matched for *valence* (consistent: $M = 2.75$, $SD = .51$; inconsistent: $M = 2.64$, $SD = .58$; t (9) = .364, $p = .724$) and *arousal* (consistent: $M = 6.70$; $SD = .79$; inconsistent: $M = 6.48$; $SD = .64$); t (9) = .932, $p = .376$), based on normative data (Stadthagen-Gonzalez, Imbault, Sánchez & Brysbaert, 2017, see Appendix B - Table 3 in Supplementary materials). Finally, a normative study ($n = 53$) with a four-point scale (from 0 'not consistent' to 3 'very consistent') showed that semantic consistency between the critical sentences and their preceding clinical cases was significantly higher for consistent ($M = 4.13$; $SD = .19$) than for inconsistent ($M = 0.33$; $SD = .24$, t (14) = 23.484, $p < .001$) sentences.

Self-rating measures

After each experimental block, participants performed two self-rating measures. First, *cognitive complexity* was measured via four items, tapping on perceived difficulty, perceived task complexity, performance confidence, and emotional exhaustion. Second, *perception of patients' mental states* was assessed via seven items, each tapping on a theory-of-mind dimensions with five-point Likert scales (from 1 'very low' to 5 'very high'). Cronbach's alpha for the present sample was .83 and .84 for both measures respectively (full description of self-rating scales are presented in Appendix C, in Supplementary Material).

2.3. Procedure

The experiment included five steps: (1) Participants read clinical cases and were asked to respond to a procedural decision task or a communicative decision task with three-alternative choice question; (2) Participants read a continuation sentence presented word-by-word; (3) Participants read 6 critical sentences, one after the other in random order, also presented one word at a time; (4) at the end, participants responded to a set of self-rating task, related to cognitive complexity and mental state inferences.

The general procedure is shown in Figure 1. Participants were asked to read each clinical case at their own pace and to answer the three-alternative choice question, also without time limit. Responses were recorded, and no feedback was given to the participants. Their response triggered a 300-ms fixation point, followed by the continuation sentence, which appeared one word at a time. In each trial, after the continuation sentence, critical sentences were presented word by word on the screen automatically: 2 semantically consistent sentences + 2 semantically inconsistent sentences, also 2 emotionally neutral sentences were employed as fillers. Each critical sentence was formed by four words. The presentation temporal pattern of the critical sentences and the fillers paced as follows (see Figure 2): Fixation point in the middle of the screen (300 ms), blank (500 ms), three words presented sequentially in the middle of the screen (400 ms + 200 ms blank), and the last word (600 ms + 800 ms blank). Participants were asked to avoid eye movements and blinks while reading the critical sentences. In trials with a verification task (40%) a question mark was depicted (1000 ms + 200 ms blank) preceding the probe sentence (¿Se sentía Pedro preocupado? [*Did Peter feel distressed?*]) participants were prompted to agree (“yes” response) or disagree (“no” response) based on the given information. The order of blocks and response buttons were counterbalanced across participants. Within each block, trials were presented in a fixed random order, as were the critical sentences within each trial. After finishing each block of clinical cases (procedural decision or communicative decision), participants completed the *cognitive complexity* and the *perception of patients' mental states* self-rating scales. All stimuli were presented on a high-resolution 24-inch monitor placed at 80 cm from the participant, at eye level. The experiment ran on E-prime software (version 2.1; Psychology Software Tools) and lasted roughly 40 minutes. Finally, to test whether the obtained results were linked to the individual differences in empathy and emotion regulation strategies, before the experimental session, participants were asking to complete the Spanish adaptation of the *Interpersonal Reactivity Index* (Pérez-Albéniz *et al.*, 2003), capturing cognitive and affective components of empathic dispositions (IRI: Davis, 1980), and the Spanish adaptation of the *Emotion Regulation Questionnaire* (Cabello *et al.*, 2013), tapping on emotion-regulation strategies of cognitive reappraisal and expressive suppression (ERQ: Gross & John, 2003).

Insert Figure 1 here

Fig. 1. Outline of the general procedure of the Experiment in the case of the Procedural decision task.

Note. The temporal sequence of the critical and filler sentences is detailed in Figure 2.

Insert Figure 2 here

Fig. 2. Outline of an experimental trial with a semantically consistent sentence (in original Spanish).

2.4. EEG recording and pre-processing

Participants' EEG was recorded continuously using a Compumedics Neuroscan (version 4.5) system from 60 active electrodes mounted in a Quick-Cap elastic cap following the 10/20 system, also, additional electrodes were placed on the left and right mastoids. An electrode at vertex (Cz) served as reference. The signal was amplified (SynAmps2) and digitized at a sampling rate of 500 Hz. A band-pass filter from .1 to 100 Hz with filter slopes of -12 dB/octave was applied online. The impedance of the electrodes was kept below 5k (ohms). For the ERP analyses, the EEG data preprocessing was conducted using Matlab Toolbox Fieldtrip (Oostenveld *et al.*, 2011). We applied the following transforms to each participant´s recording. Dataset was low pass-filtered at 30 Hz and re-referenced to both mastoids.. EEG segments were extracted from a trigger time locked over the adjective (e.g., distressed). The latency of the epochs included an interval of 200 ms preceding the onset of the target word, and extending 1400 ms afterwards. Artifacts due to blinks were corrected using ICA (Independent Component Analysis). For these segments, we executed artifact removal in two stages. Initially, we applied the semiautomatic fieldtrip artifact removal function to screen the data for potential artifacts by thresholding z-scored values from preprocessed signals. This method can effectively identify artifacts such as EOG or muscle disturbances. In this application, trials that surpassed a 2.5 z threshold in EEG channels were automatically detected and discarded. Finally, the resulting ERP was visually inspected. For the computation of ERPs, artifact free segments were finally averaged separately for each of the 4 experimental conditions: “Procedural decision task + Consistent sentence”, “Procedural decision task + Inconsistent sentence”, “Communicative decision task – Consistent sentence”, “Communicative decision task – Inconsistent sentence”.

2.5. ERP amplitude analysis

No trials were excluded based on the provided responses. Thus, all the experimental trials that remained after artifact removal for each condition and subject were included in the analysis. The analysis was performed over the target word, the adjective, following a two-step procedure. First, based on hypothesis, we selected the waveforms based on the components (EPN, N400 and LPP), then we identify them based on visual inspection, resulting in three time-windows ($TW1_{EPN}$: 300 – 400 ms; $TW2_{N400}$: 460–740 ms; $TW3_{LPP}$: 1250 – 1350 ms.). This integration of hypothesis-based and data-driven methods ensures a reliable selection of waveforms corresponding to the cognitive processes we intended to investigate. The time windows were decomposed using the non-parametric cluster randomization test implemented in Matlab Toolbox Fieldtrip (Oostenveld *et al.*, 2011). This approach allows us to report scalp distribution of significant differences between pair conditions and explore interactions between factors. In particular, the average amplitude of each scalp site for the intervals selected on visual inspection were taken as input, and the randomizations test revealed when up to 3 electrodes (cluster > 3) reached significance ($p < .05$) applying cluster analysis corrections. Upon identifying an interaction in TW3, we proceeded to decompose it by examining the effects of Task at each Consistency level (“Procedural decision task – Consistent sentence” vs. “Communicative decision task – Consistent sentence”; “Procedural decision task –Inconsistent sentence” vs. “Communicative decision task – Inconsistent sentence”). The *p*-values and confidence intervals (CI) are reported.

3. Results

3.1. Behavioral results

Accuracy in the three-alternative choice question

As shown in Figure 3, accuracy was significantly higher t (39) = 11.757, $p < .001$) on the communicative decision ($M = .96$; $SD = .05$) than on the procedural decision task ($M =.75$; $SD = .11$).

Insert Figure 3 here

Fig. 3. Accuracy in the three alternative choice questions as a function of Task (procedural decision/communicative decision). ***$p < .001$

Verification task

Accuracy on the verification task did not differ significantly (t (39) = .055, $p = .956$) between procedural ($M = .86$, $SD = .17$) and communicative ($M = .86$, $SD = .18$) trials (Figure 4). High accuracy in the verification task allows us to ensure that participants were engaged in the comprehension of the critical sentences. Upon exclusion of incorrect responses (14.28%) and responses 2 SDs above participants' means (4.64 %), performance speed did not differ significantly (t (39) = .892, $p = .378$) between procedural decision (M = 2579 ms, SD = 670.33 ms) and communicative decision (M = 2691 ms, SD = 644.11 ms) trials.

Insert Figure 4 here

Fig. 4. Response Times and accuracy in the verification task as a function of Task (procedural decision/communicative decision).

Self-rating measures

Ratings of *cognitive complexity* showed that, relative to the communicative decision task, the procedural decision task was perceived as more *difficult* (M = 2.87, SD = .69, for procedural; M = 2.26, SD = .80, for communicative; t (39) = 4.382, p < .001) and more *complex* (M = 2.83, SD = .78, for procedural; M = 2.30, SD = .82, for communicative; t (39) = 3.92, p < .001), yielding less confident responses (M = 3.43, SD = .75, for procedural; M = 4.13, SD = .65, for communicative; t (39) = 6.445, p < .001); *emotional exhaustion* did not differ significantly between conditions (M = 2.60, SD = .82, for procedural; M = 2.63, SD = 1.01, for communicative; t (39) = .239, p = .813). As regards the perception of patients' mental states, responses were higher in the communicative decision task (M = 4.16, SD = .54) than in the procedural decision task (M = 3.98, SD = .61; t (39) = 6.445, p < .01) - Figure 5.

Insert Figure 5 here

Fig. 5. Participants' punctuation in the self-rating measures as a function of Task (procedural decision/communicative decision). **p < .01; ***p < .001.

3.2. ERP results

EPN

In the 300-400 ms window, the communicative decision condition elicited less negative amplitudes than the procedural decision condition over parieto-occipital electrodes (p = .008, CI = .0055) (Figure 6A). Less negative amplitudes were also observed for inconsistent than for consistent sentences in occipital, parietal, central, and right fronto-central electrodes ($p < .001$, CI = .002) (Figure 6B).

Insert Figure 6 here

Fig. 6. ERP waves in 3 representative electrodes in the midline, time-locked to the critical word (*distressed*). The interesting time windows (TW) for each comparison, obtained by a two-step procedure hypothesis and statistical data driven procedure, were signaled with a vertical gray box. The white spots in the maps correspond to the electrodes included in significant topographical clusters for each pair-wise comparison for the whole window. The ERP waveforms were smothered for graphical purposes. **A** (top) Comparison of main effects of Procedural decision (Red) and Communicative decision (Blue) task. **B** (down) Comparison of main effects of Consistent (Red) and Inconsistent (Blue) sentences.

LPP

In the 1250 – 1350 ms window, Task and semantic consistency revealed a significant interaction (p = .048). The communicative decision-consistent condition elicited larger positive amplitudes compared to procedural decision-consistent condition (p = .018, CI = .008) on bilateral central electrodes (Figure 7); while the communicative decision-inconsistent condition and the procedural decision-inconsistent condition did not differ ($p > .05$) (Figure 7). In addition, larger positive amplitudes were observed for inconsistent than consistent sentences ($p < .004$, CI = .004) broadly distributed on central electrodes (Figure 6B).

N400

Finally, as expected, in the 460 – 740 ms window, inconsistent sentences elicited larger negative amplitudes than consistent sentences ($p < .001$, CI = .002) broadly distributed all over the scalp (Figure 6B).

Insert Figure 7 here

Fig. 7. Comparison of consistent sentences in procedural decision (Red) and communicative decision (Blue) task. ERP waves in 9 electrodes, time-locked to the emotional critical word (*distressed*). The interesting Time Window (TW) was obtained by a two-step procedure - hypothesis and statistical data-driven- and signaled with a vertical gray box. The white spots in the map correspond to the electrodes included in significant topographical clusters for the pair-wise comparison for the whole window. The ERP waveforms were smoothed for graphical purposes.

ERP components, individual differences measures and self-rating measures

We aimed to explore the relation of the LPP component as a function of the *cognitive complexity* and the *perceived patients' mental states indices* associated with both conditions; and as well as of the individual differences in the IRI (*Interpersonal Reactivity Index*) and the ERQ (*Emotion Regulation Questionnaire*).

To this end, we calculated the difference between the amplitudes associated with the LPP cluster for the procedural and the communicative trials. Also, we calculated the difference of the punctuations of the *cognitive complexity* and *perceived patients' mental states* for both tasks. On a second step, we correlated the differential of the LPP component with the differential of these measures. This simple manipulation helps us better understand the direction of the results: a positive correlation implies that an increase in either behavioral measure is associated with a positive increase in the component. LPP amplitude was positively correlated with all three subjective ratings of *cognitive complexity*, namely, difficulty (r = .399, p = .011), complexity (r = .554, p < .001), and emotional exhaustion (r = .444, p = .004). These results show that increased activation of the LPP for the communicative decision task was borne out by greater ratings on cognitive complexity for the communicative decision task (compared to procedural decision task). No other differences arose.

We performed a similar analysis associated with the EPN cluster; however, no significant correlations were found between the differential EPN amplitude ratings of *cognitive complexity* or *mental state inferences*. Neither the ratings in the IRI, nor in the ERQ were significantly correlated to the electrophysiological components analyzed.

4. Discussion

The primary goal of this study was to examine the effects of the type of clinical task on emotion-related ERP modulations –the EPN and the LPP components– as well as their relationship with self-rating measures of *cognitive complexity* and *mental state inferences*. Our findings suggest that the type of task that nursing students are required to do produces differences in early and late processing of emotional information, as indexed by the EPN and the LPP ERPs.

The current research demonstrated effects of the type of clinical task on a sequence of relatively early (EPN component) and late (LPP component) psychophysiological indices. Initially, we found different brain responses to words with emotional –negative valence– content depending on the clinical task. Specifically, the procedural decision task elicited larger negative amplitudes than the communicative decision task in the EPN component. At later stages, we found larger positive amplitudes in the communicative decision-consistent condition compared to the procedural decision-consistent condition, which were associated with higher ratings of perceived cognitive complexity.

Differences marked by negativity in the EPN component are likely to involve initial categorization of the stimuli, which seems to reflect the catching of attention resources by their emotional significance (Schacht & Sommer, 2009b; Palazova *et al.* 2013, among others). Our results support the notion that, initially, emotional information recruits more attentional resources in the context of the procedural decision task compared to the communicative decision task, regardless of their semantic consistency. This suggests that emotional information is more salient for nursing students in a technical diagnosis situation than in a communicative context. This result seems to be due to the participants' endogenous state induced by the task, given that the stimuli are exactly the same and they were controlled in terms of arousal and emotional valence. One possible explanation for these results is that, in a communicative context, professionals should focus on expressing information in the best possible way according to the needs of their patients and their possible emotional reactions (Arora *et al.*, 2010). Therefore, they have a proper frame of mind to integrate and process the incoming target emotional sentences. On the contrary, in the procedural decision context, clinicians are more focused on solving a problem efficiently, and the emotional sentences would initially demand more attention.

Processing marked by late positivity (LPP) is likely to involve sustained elaboration of emotional stimuli, related to greater evaluation, encoding, integration, recategorization, etc., of the stimulus significance (Hajcak *et al.*, 2010; Herbert, Junghofer & Kissler, 2008; Kok, 1997). As we have said, some authors consider that later elaborative processing stages could be particularly relevant for *emotion regulation processes* (Krendl *et al.*, 2017; Schindler & Bublatzky, 2020). Specifically, the magnitude of the LPP component has been interpreted as an index of whether or not regulatory processes are successfully engaged when evaluating negative stimuli (Krendl *et al.*, 2017; Hajcak & Nieuwenhuis, 2006; MacNamara *et al.*, 2011). Our results indicate that LPP amplitudes were significantly reduced for consistent stimuli in the procedural decision compared to the communicative decision task. It is unclear whether this results from a reduced attentional resources to those stimuli (Schindler & Kissler, 2016; Schindler & Straube, 2020; Schupp *et al.*, 2007; Weinberg, Hilgard *et al.*, 2012), or from a change in the emotional meaning and the impact of the stimuli, more in line with the strategy if reappraisal emotional regulation (Gross & John, 2003; Hajcak & Nieuwenhuis, 2006; Moser *et al.*, 2006). Considering that the two types of clinical tasks require different socio-cognitive skills, our results support the idea that further elaboration of emotional information is a requirement of communicative decision tasks, whereas it is not elicited by procedural decision tasks.

Significant correlations between the differential LPP amplitude and subjective ratings in *cognitive complexity* suggests that the brain activity associated with the elaboration of emotional stimuli is positively associated with the level of cognitive complexity perceived by participants. This result suggests that participants' subjective assessments of the level of difficulty of the experimental tasks have an objective brain correlate in the EEG marked by the LPP.

Regarding the main effect of semantic inconsistency, we found significant effects in all the analyzed ERPs components. An important result of the present study is the classical N400 effect elicited by semantic inconsistent sentences compared to consistent ones. This widely verified semantic effect was independent of the type of task manipulation and indicates that participants are processing the experimental sentences meaning correctly. Additionally, compared to consistent sentences, inconsistent sentences elicited less negative amplitudes in the EPN and larger positive amplitudes in the LPP. These results indicate that, initially, inconsistent sentences require less attentional resources than the consistent ones, while in later processing stages, inconsistent sentences require a greater elaborative processing than consistent sentences (Baetens *et al.*, 2011; Bartholow *et al.*, 2001; Foucart *et al.*, 2015). Notice that in the present experiment, the observed modulations in the emotional-sensitive ERP components (EPN, LPP) did not respond to explicit instructions to participants nor to intrinsic emotional properties of words (arousal + valence), that were controlled for all critical sentences. The fact that the type of task was performed before subjects processed the corresponding emotional sentences demonstrates the potential for specific clinical tasks requirements to modulate the processing of emotional stimuli in medical contexts.

Several implications emerge from this study. Nurses and physicians must adeptly interpret patients' emotional states during interactions, fostering trust and ultimately leading to improved clinical outcomes. Interestingly, emotions could provide crucial information to be more effective in decision making (Hermann et al., 2016). In this sense, during procedural decisions, patients' emotional responses might need to be considered for several reasons, such as promoting the implication of patients in their own treatment or reducing the likelihood of medical errors in diagnosis. Theoretical models of clinical decision-making typically emphasize the technical and cognitive dimensions of reasoning (Watkins, 2020), traditionally associated with the brain executive system. However, emotional input from patients plays a vital role in both clinical reasoning —the cognitive processes involved in assessing and integrating available information within clinical contexts— and clinical decision-making — selecting the most appropriate course of action based on patient-centred and evidence-based approaches (Kozlowski et al, 2017). Our findings suggest that healthcare professionals' attention to or dismissal of distressing emotional information from patients may vary depending on the nature of the clinical tasks they encounter. From this perspective, our results could indicate that focusing on procedural or communicative tasks may condition the analysis of critical emotional information, which can be crucial for understanding patients' health status. Importantly, the lack of elaboration or integration of emotional information in procedural decision-making has been shown to lead to increasing the likelihood of committing diagnostic errors (Liu, 2022). On this behalf, our results indicate that differences observed are not attributable to a lack of attention to emotional signals, but rather to a diminished reevaluation of such information.

These findings suggest that healthcare professionals' attention to or dismissal of patients' emotional cues may vary depending on the nature of the clinical tasks encountered, potentially influencing diagnostic accuracy. However, there are situations where a patient's emotional state clashes with optimal clinical decisions, raising questions about the balance between emotional consideration and clinical efficacy. Future studies could explore whether the optimal outcome lies in procedural decisions that precisely integrate emotional factors, when necessary, while also recognizing situations where ignoring emotions may be appropriate for achieving the best health outcomes. In this vein, future research should explore nuanced approaches that accommodate both patient emotions and clinical efficacy, fostering a more comprehensive understanding of decision-making dynamics in healthcare settings.

Future research will help to more precisely identify the underlying processes involved in procedural decision tasks as well as in communicative decision tasks in clinical contexts. In addition, future research could explore the effect that processing emotional information differently in each type of task could have in the efficacy, efficiency of ER strategies displayed for the healthcare professionals. Furthermore, future studies could incorporate the patient's responses towards a higher or lower interest in their emotional states while they're involved in a clinical decision-making process. Future studies should also incorporate supplementary contextual cues that could impact how healthcare professionals strategically process and interpret emotional information.

Our study presents several limitations that should be considered. Although we do not have any hypothesis about the role of time of experience, it should be noted that our sample was formed by nursing students finishing their formative process, ranging between 18 and 39 years old. In addition to the time of experience as healthcare professionals, other confounding variables should be studied in future research, such as the amount of contact with patients depending on the service, or the empathic orientation. Despite this limitation, findings and implications of the present study are pertinent not only to current nursing students but also to the wider healthcare provider community, including those in training and those already practicing. Furthermore, the aim of this research is focused on the processing of emotional information of our sample of interest, and not compared with a sample which is not related or familiarised with healthcaring contexts. Future studies may account for generalizability of these processes in other fields of expertise requiring social navigation and complex decision-making processes that involve emotional, technical and cognitive dimensions of reasoning, such as human resources, clinical psychology, social working, teaching, law, etc. Despite these constraints, the present research contributes to the existing literature on clinical decision-making and emotion regulation by demonstrating that procedural decision tasks and communicative decision tasks display a different pattern of response in nursing students toward subsequent emotional information from patients.

In sum, by using ERP, the current study provides evidence that the type of clinical task modulates patterns of brain activity related to the processing of emotional information. We found a significant main effect of the task in a relatively early time window (EPN component), according to which procedural decision task was associated with increased electrophysiological activity in processing emotional information as compared with communicative decision task. Further, we found a significant interaction effect in a late time window (LPP component), according to which, brain activity associated with consistent trials in the context of communicative decision task was significantly different from activity associated with consistent trials in the context of procedural decision task (more positive). These differences were not influenced by valence and arousal of the stimuli (emotional words were the same in all the experimental conditions). Then, our results show the potential for the type of clinical task to influence the processing of emotional stimuli eliciting different brain responses in both the initial categorization (as indexed by the EPN component) and the later elaborative processing of emotional stimuli (as indexed by the LPP component). According to the correlational analysis, differences between the communicative decision task relative to the procedural decision task in the LPP seem to be associated with a greater perception of task complexity by the participants and cannot be attributed to their differences in dispositional empathy traits or ER strategies trends, reinforcing the fact that they are due to the type of task.

Data availability

The data underlying this article are available in Open Science Framework (https://osf.io/) at https://osf.io/reawy/?view_only=d28e243fad1b4fd6ae11a77b9df33862

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