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Two social minds in one brain? error-related negativity provides evidence for parallel processing pathways during social evaluation

Nassim Elimari¹, Gilles Lafargue² *

^{1,2} *Université de Reims Champagne Ardenne, C2S, EA 6291, France.*

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*Correspondance : Gilles Lafargue, Université de Reims Champagne-Ardenne, Laboratoire C2S, B.P. 30, 57 rue Pierre Taittinger, REIMS Cedex 51171. E-mail: gilles.lafargue@univ-reims.fr

Abstract

Several authors assume that evaluative conditioning (EC) relies on high-level propositional thinking. In contrast, the dual-process perspective proposes two processing pathways, one associative and the other propositional, contributing to EC. Dual-process theorists argue that attitudinal ambiguity resulting from these two pathways' conflicting evaluations demonstrate the involvement of both automatic and controlled processes in EC. Previously, we suggested that amplitude variations of error-related negativity and error-positivity, two well-researched event-related potentials of performance monitoring, allow for the detection of attitudinal ambiguity at the neural level. The present study utilises self-reported evaluation, categorisation performance, and neural correlates of performance monitoring to explore associative-propositional ambiguity during social attitude formation. Our results show that compared to associative-propositional harmony, attitudinal ambiguity correlates with more neutral subjective evaluations, longer response times, increased error commission, and diminished error-related negativity amplitudes. While our findings align with dual-process models, we aim to offer a propositional interpretation. We discuss dual-process theories in the context of evolutionary psychology, suggesting that associative processes may only represent a small piece of the EC puzzle.

Keywords

Dual-process cognition; evaluative conditioning; event-related potential; social evaluation; evolutionary psychology

1. INTRODUCTION

Attitude formation refers to the cognitive processes that shape and adapt beliefs and sentiments toward all elements of the environment. Since the seminal paper of Levey and Martin (1975), extensive research has validated evaluative conditioning (EC) – i.e. the change in attitude toward an initially neutral conditioned stimulus (CS) due to its repeated pairing with a valent unconditioned stimulus (US) – as the main source of attitude formation (De Houwer et al., 2001; Gawronski & Bodenhausen, 2006; Hofmann et al., 2010; Walther et al., 2005, 2011). The propositional theory of EC (De Houwer, 2007) assumes that attitude formation results from the rational, deliberative, conscious production of propositions, i.e. mental statements about the relation between two or more stimuli. Changes in liking follow CS-US pairings because a newly encoded proposition crystallises the relation between the two stimuli (e.g. “this CS causes this negative US” warrants a negative attitude toward the CS, while “this CS prevents this negative US” warrants a positive attitude). The propositional theory accounts for most of the disposable data on the subject (Hofmann et al., 2010) and there is little doubt that high-level propositional mechanisms process CS-US links to form attitudes. However, one of the most hotly debated topics in the EC literature (Baeyens et al., 2009; Corneille & Mertens, 2020; Gawronski & Bodenhausen, 2018; Hütter, 2022; Moran et al., 2016, 2023) is whether a second set of

automatic processes (i.e. fast, effortless, uncontrollable, unintentional, unconscious¹) also forms attitudes in a parallel and implicit manner, as predicted by dual-process theories of attitude formation (Gawronski & Bodenhausen, 2006; Morewedge & Kahneman, 2010; Rydell & McConnell, 2006).

1.1. *Dual-process versus propositional theories of attitude formation*

The neural demands associated with the uniquely evolved human high-level cognition required, over evolutionary time, slow gradual changes in the brain's neurocognitive architecture (Anderson, 2014, 2016; Badcock et al., 2019; Elimari & Lafargue, 2020). Before the advent of the modern complex and flexible human mind, the brain relied on more primitive processes to solve most adaptive challenges, most of which are assumed still active in contemporary human cognition². These premises are the fundamental theoretical basis for the dual-process perspective of human cognition (Evans, 2011; Evans & Stanovich, 2013; Gawronski & Creighton, 2013; Kahneman, 2011; Sloman, 1996; Smith & DeCoster, 2000), a set of models that highlight the figurative division of the mind between phylogenetically old, low-level, automatic processes (or type I processes), and phylogenetically recent, high-level, controlled processes (type II processes). Whether type I processes are at play in EC is a relevant yet not easily answered question. Dual-process theories of attitude formation propose that EC results from an interplay between parallel type I and type II processing pathways. For instance, the associative-propositional evaluation model (Gawronski & Bodenhausen, 2006) proposes that two distinct systems can form attitudes: a type I associative system that automatically processes mere spatiotemporal CS-US contiguity regardless of their relation; and the previously evoked type II propositional system.

The Dual-EC vs propositional-EC debate thus centres around the possibility of automatic attitude formation that is paralleled to the conscious processing of CS-US relations. Dual-EC and propositional-EC accounts therefore make competing assumptions regarding several topics: one of them is the possibility for attitudinal ambiguity to arise from conflicting associative and propositional evaluations. Indeed, and contrary to their propositional counterparts, associative processes are blind to complex relations and thus always assimilative by nature: US valence is blindly transferred to the CS, regardless of actual CS-US relationship. Therefore, the dual-EC account assumes that CS-US pairs linked by a contrastive relation (e.g. "CS is the opposite of US", "CS prevents US"), will induce conflicting (i.e. incongruent) associative and propositional evaluations, hence the attitudinal ambiguity.

Thus, the possibility for automatic EC can be tested using a paradigm with a seemingly unique aim (from the perspective of the participant) of forming attitudes based on relational information, but with a secondary unspoken pathway to EC (1) that is strictly mediated by associative rules, (2) to which participants remain incognisant, and (3) that produces parallel

¹ Note that "unconscious" refers to the fact that automatic processes do not need to be consciously monitored to occur, not that they occur without stimulus perception, that their cognitive end-product is not consciously accessible, or that it does not affect phenomenology in any way, shape, or form.

² See Dawkins (1982) for an explanation as to why natural selection is not a human engineer but a blind designing process that does not erase previously evolved mechanisms when new adaptations render them obsolete.

evaluations that are either harmonious (i.e. congruent) or conflicting (i.e. incongruent) with relational information. Using such incongruent EC paradigm, several studies showed with both explicit and implicit measures that congruent CSs and incongruent CSs are processed differently: relational information systematically yield an EC effect, but mere co-occurrences also drives attitudes such that CSs that co-occur with positive USs are preferred to CSs co-occurring with negative USs, regardless of relationship (Gawronski et al., 2005; Moran et al., 2015, 2016; Moran & Bar-Anan, 2013, 2020; Peters & Gawronski, 2011; Rydell & McConnell, 2006). For instance, Moran and colleagues (2015) found that helpful creatures who started positive events (i.e. positive congruent CSs) were preferred over helpful creatures who ended negative events (positive incongruent CSs), while harmful creatures who ended positive events (negative incongruent CSs) were preferred over harmful creatures who started negative events (negative congruent CSs). In a similar vein, a recent study observed more attitudinal ambiguity (both self-reported and inferred from mouse-tracking measures) toward incongruent than toward congruent CSs (Béna et al., 2022). This repeatedly observed attitudinal ambiguity has been considered sound evidence in favour of automatic EC: in simple terms, no associative-propositional ambivalence could emerge without associative processes.

1.2. Physiological data in evaluative conditioning

Though the quest for more objective measures is often regarded as a crucially relevant part of research on automatic cognition, researchers have seldom relied on physiological measures as a way to approach the dual-EC vs propositional-EC debate. In a previous study (Elimari & Lafargue, 2023), we proposed a new avenue for highlighting attitudinal ambiguity using neural correlates of performance monitoring (PM), a set of neurocognitive mechanisms implicated in error detection and adjustment of goal-directed behaviours (Dehaene, 2018; Falkenstein et al., 1991; Gehring et al., 1993, 2012, 2018; Yordanova et al., 2004). The PM system works based on a comparator function that detects conflicts between (1) intended and actual responses and (2) expected and actual response outcomes (Alexander & Brown, 2010; Coles et al., 2001; Holroyd & Coles, 2002; Scheffers & Coles, 2000). The detection of error-related conflict by the PM system leads to its overactivation, as reflected in the emergence of two event-related potentials coined error-related negativity (ERN, a fronto-central negative deflection that peaks between 0 and 100ms after error commission) and error-positivity (Pe, a centro-parietal positive wave that peaks between 200 and 500ms). Given its early onset and its relative independence from error-awareness, the ERN is viewed as a neural index of automatic error detection, while Pe is thought to reflect the conscious awareness of error commission (Di Gregorio et al., 2018; Herrmann et al., 2004; Nieuwenhuis et al., 2001; Orr & Carrasco, 2011; Overbeek et al., 2005).

Neural correlates of PM constitute an optimal candidate for highlighting attitudinal ambiguity: on the most fundamental level, attitudes are guides to actions, prepared affective states toward specific cues that facilitate “appropriate” behavioural responses (Chaiklin, 2011; Jain, 2014; Lord et al., 2015; Petty et al., 2007; Van Overwalle & Siebler, 2005). Since PM works based on a comparator function that indexes degrees of divergence between intended (correct) and actual (erroneous) actions, we hypothesised that attitudinal ambiguity would disrupt error-related conflict detection because it would trigger the co-activation of two mutually exclusive motor programmes: a “propositional” one matching the mental representation of the correct response

and another “associative” one that matches the wrong response. In case of error, the “propositional mind” understands that an error has been made, while the “associative mind” whispers that it was the right answer. We thus conditioned congruent vs incongruent attitudes toward a set of CSs and asked participants to categorise them according to their propositional valence, expecting incongruent CSs to be associated with altered neural correlates of PM. Consistent with the dual-EC account, participants displayed diminished amplitudes of both ERN and Pe for incongruent CSs, reflecting the disruption of PM. To our knowledge, our study constitutes the only direct test of hypotheses derived from dual-EC versus propositional-EC accounts using neural correlates of attitude processing.

1.3. The present study: the special case of social attitude formation

There is limited range in the conclusions drawn from a single experiment (Elimari & Lafargue, 2023) and replication studies must be carried out. Moreover, a specific question is to be asked regarding social attitudes: are there domain-specific variations in the involvement of associative and propositional processes as a function of stimulus nature? Given the complexity and evolutionary recency of social cognition, several authors have proposed that human high-level cognition is a by-product of social intelligence (Dunbar, 1998; Dunbar & Shultz, 2007; Gavrillets & Vose, 2006; Holloway, 1967; Humphrey, 1976). As we have argued before (Elimari & Lafargue, 2020, 2023), it is therefore logical to assume that social processes involve high-level processes to a higher degree than other forms of processes. Consequently, our previous results on semantic CSs might not be applicable to social attitude formation, as social EC could operate on the foundation of more propositional processes than EC of words, furniture, or pieces of art. The present study assesses whether congruent and incongruent social CSs are processed differently through the use of both behavioural (i.e. reported subjective evaluation, Speeded Go/No-Go) and neurophysiological data. Based on prior studies relying on the incongruent EC paradigm (Elimari & Lafargue, 2023; Moran et al., 2015, 2016; Moran & Bar-Anan, 2013, 2020; Peters & Gawronski, 2011; Rydell & McConnell, 2006), we err on the side of the dual-EC account and hypothesise that, compared to congruent CSs, incongruent CSs will be associated with more neutral perceived valence, increased response times and errors, and diminished amplitudes of both the ERN and Pe.

2. METHODS

2.1. Participants

We recruited 45 native French speakers (60% females) between the age of 18 and 59 ($M = 25.42$, $SD = 8$) through the use of flyers. The study was designed in accordance with the Declaration of Helsinki and all participants gave their written informed consent after receiving a full description of the study. Participants were not compensated for their participation and could retract at any point of the study without having to justify themselves.

2.2. General procedure

Participants were installed in a dim lit room in front of a 17” screen computer. The procedure was implemented using E-Prime 2 Professional (Psychology Software Tools, Pittsburgh, PA, USA) and comprised two phases: a first conditioning phase consisting of an incongruent EC

paradigm, and a second evaluating phase where participants (1) reported their subjective evaluation of all CSs and (2) manipulated CSs in a Speeded Go/No-Go (Figure 1).

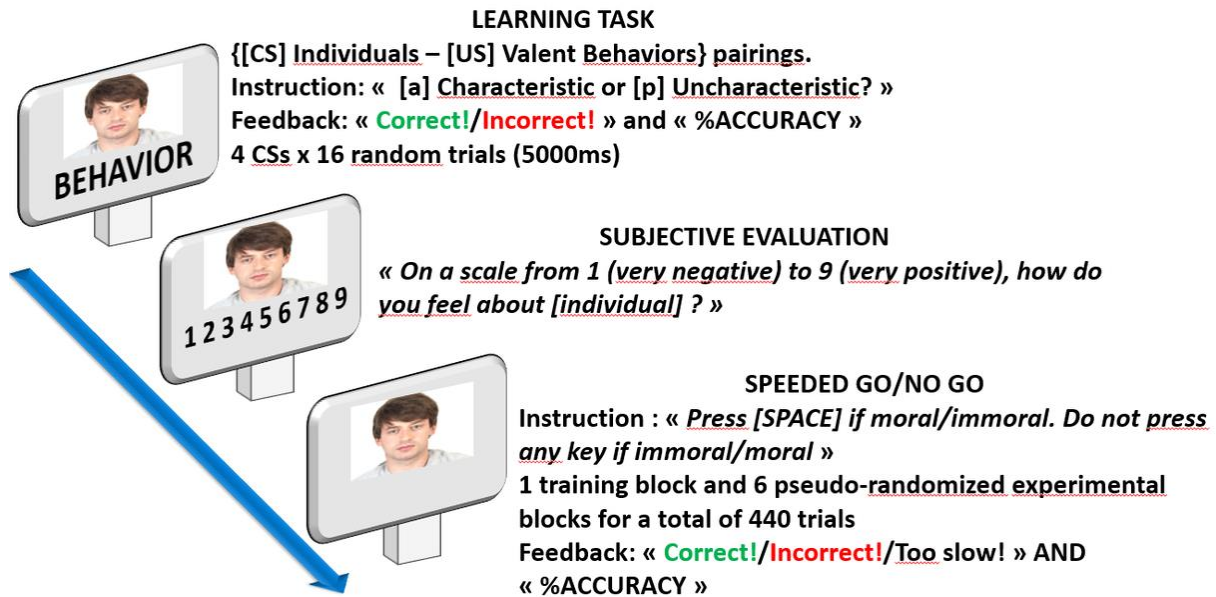


Figure 1. Visual representation of the three-phase experiment. First came (a) the conditioning phase (lasting about 5 min), during which attitudes were conditioned toward four coworkers. Second phase (lasting about 1 min) consisted of (b) subjective ratings of the 4 coworkers on Likert scales ranging from 1 (“extremely negative”) to 9 (“extremely positive”). Third phase (lasting between 12 and 15 min) was (c) a Speeded Go/No Go: after 40 training trials during which average RT was registered, participants underwent six sessions of 60 trials (three sessions where positive CSs had to be categorised, three others where negative CSs had to be categorised, presented in a pseudo-randomized order) during which participants’ RT had to be below 90% of their average speed. Electrophysiological data was recorded during the Speeded Go/No-Go only.

2.2.1. Conditioning phase

The incongruent EC paradigm was presented in the form of a game (see supplementary materials for more details) where participants “prepared” for future interactions with four fictive coworkers (CSs) by forming an attitude toward them based on example valent behaviours (USs)³. Participants were explicitly informed that these behaviours had not been enacted and merely served as examples that helped to learn about each coworker’s personality traits and overall moral character. Participants had to press either “a” or “p” to report whether they thought the behaviour was characteristic or uncharacteristic of each co-worker, respectively. Participants had no information at the beginning of the task but slowly learned as they formed an attitude toward each individual. The relational link (i.e. “characteristic” vs “uncharacteristic”) determined the propositional evaluation (henceforth referred to as “Morality” for convenience purposes), while CS-US pairings determined the associative evaluation. For instance, if a coworker consistently co-occurred with immoral behaviours and

³ To clarify, the relationship between “valence” and “morality” was strictly limited to the manipulation of valence as a function of USs’ degree of morality. Please note that this study is neither about moral cognition nor that morality is to be here understood as a semantic category.

relational link was “characteristic”, then associative and propositional processes worked in harmony to form a congruent negative attitude. If, however, a coworker co-occurred with immoral behaviours and the relational link was “uncharacteristic”, then only the propositional system would evaluate the individual as moral, while sheer repetitions of CS-US pairings would result in a negative associative evaluation (i.e. incongruent positive attitude).

2.2.2. Evaluation phase

First, participants were required to provide their subjective attitude toward each coworker on a Likert scale ranging from 1 to 9, with 1 reflecting a highly negative attitude, and 9 reflecting an extremely positive attitude.

Then, participants underwent a Speeded Go/No-Go (see Supplementary material for more details). All 4 CSs were presented in a random order and participants were asked to press the [SPACE] key if they felt that the stimuli matched conditions of the current block (e.g. “press [SPACE] if you feel like the man that appears in front of you is immoral. Otherwise, don’t press any key”). Participants went through a preliminary practice session (40 trials) and then performed six blocks of 60 experimental trials. A feedback window informed participants on (1) response correctness (“Correct!” or “Incorrect!”), (2) RT in milliseconds, and (3) average accuracy. It is important to note that correctness was indexed on propositional valence (“associative valence” was never evoked during the procedure and did not make sense within the context of the task). If participants failed to respond below 90% of their average RT, they received a message telling them that they were not fast enough (“Trop lent!” or “Too slow!”), the purpose of which was to incentivize participants to increase speed and thus to maximise the number of relevant trials (i.e. errors). Behavioural measures included the RT during correct hits as well as number of errors for each type of stimulus.

Details about EEG data acquisition, preprocessing pipeline (made with EEGLAB, Delorme & Makeig, 2004, and Brainstorm, Tadel et al., 2011), and data analyses for both behavioural and electrophysiological data, are provided in supplementary material. Mirroring our previous study (Elimari & Lafargue, 2023), we calculated ΔERN as the weighted difference between averaged correct-response activity and averaged error-related activity at electrode Cz (where amplitudes were maximal) from – 50 ms to 100 ms after motor response. The same method was used to calculate ΔPe from 200 ms to 500 ms after motor response at electrode Pz. Condition-averaged ERPs calculation of Cronbach’s alpha (Thigpen et al., 2017) for $k = 4$ conditions revealed that both ΔERN ($\alpha = 0.95$) and ΔPe ($\alpha = 0.93$) presented with good internal consistencies.

3. RESULTS

3.1. Behavioral data

A first 2 (Morality) x 2 (US valence) ANOVA revealed a predictable significant main effect of Morality on subjective evaluation scores (Figure 2), such that moral individuals were rated more positively than immoral individuals ($F(1, 44) = 91.75, p < .001, \eta^2 = .68$). Consistent with the dual-EC account, US valence also had a significant main effect, reflecting more positive subjective attitudes toward individuals who cooccurred with moral behaviours than toward individuals who co-occurred with immoral behaviours [$F(1, 44) = 33.2, p < .001, \eta^2 = .43$].

Of interest was the fact that the effect of Morality on subjective evaluations was moderated by US Valence, as shown by a significant Morality x US Valence interaction effect [$F(1, 44) = 4.71, p = .036, \eta p^2 = .12$]. That interaction revealed that, though congruent and incongruent CSs differed significantly for both moral [$t(44) = 6.38, p < .001, d = 1.24$] and immoral [$t(44) = 2.38, p = .022, d = .50$] coworkers, that difference was significantly greater for moral coworkers.

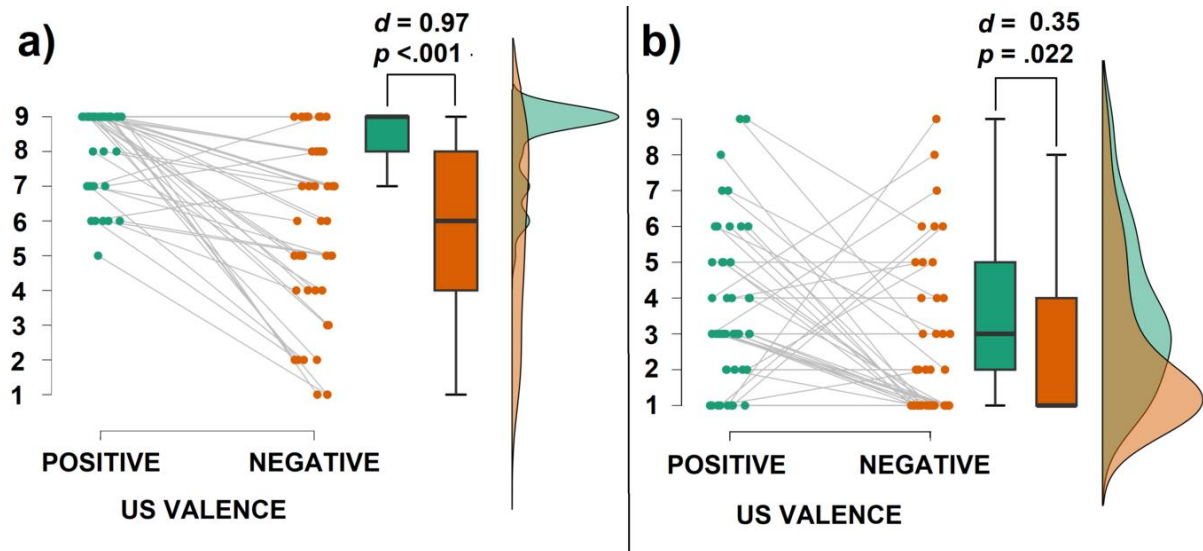


Figure 2. Raincloud, box, and density plots of subjective evaluation scores on a Likert scale from 1 (very negative evaluation) to 9 (very positive evaluation) for (a) positive conditioned stimuli (CSs) and (b) negative CSs. An evaluative conditioning effect emerged, with a clear-cut preference for individuals with an overall moral and positive character. The procedure also led to a significant “Incongruence” effect of US valence above and beyond the consciously processed moral character of coworkers: coworkers who co-occurred with positive US were preferred to coworkers who co-occurred with negative USs. P-values and Cohen’s d are provided above box plots.

The results regarding response times and error counts are depicted in Figure 3. Morality had no significant main effect on RTs [$F(1, 44) = .002, p = .963$], with both moral and immoral individuals being categorized by participants at the same speed. However, Congruence had a significant main effect on RT [$F(1, 44) = 4.9, p = .032, \eta p^2 = .10$], such that congruent CSs were categorised faster than incongruent CSs. A significant Morality x Congruence interaction effect was observed [$F(1, 44) = 10.92, p = .002, \eta p^2 = .20$], indicating that the effect of Congruence varied as a function of Morality. Paired t-tests confirmed that, while participants displayed longer RTs when categorising incongruent moral coworkers than congruent moral coworkers [$t(44) = 4.7, p < .001, d = .26$], the difference between congruent and incongruent CSs did not reach significance for immoral coworkers [$t(44) = .16, p = .87$].

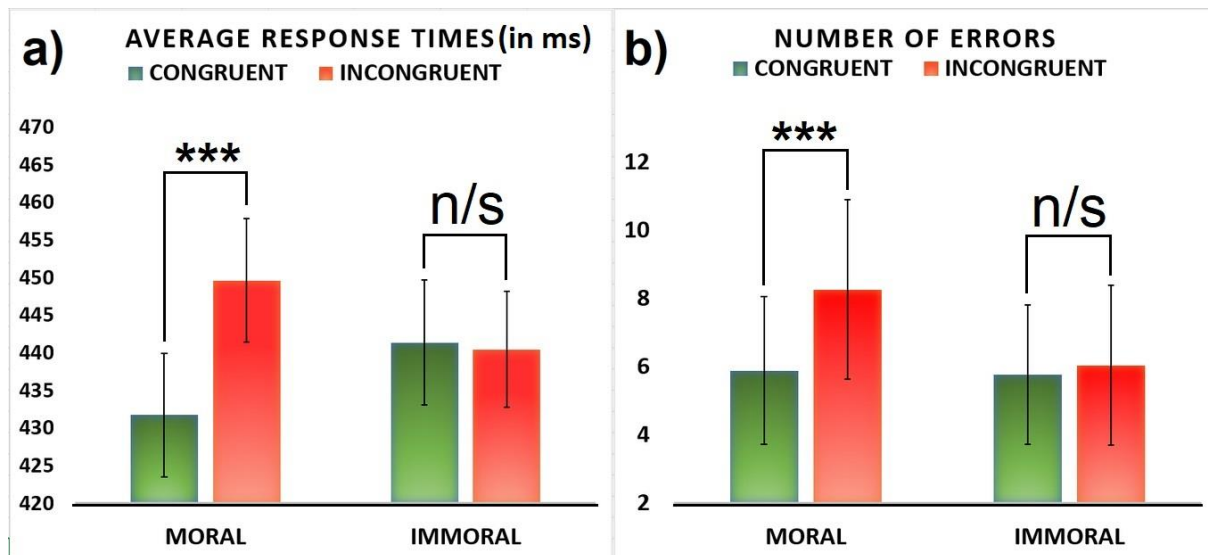


Figure 3. Behavioural data for the Speeded Go/No Go. Statistical differences between congruent and incongruent CSs in terms of (a) response times (RT) and (b) error commission reached significance only for moral coworkers. * $p < .05$, ** $p < .01$, *** $p \leq .001$. Error bars represent standard error of the mean.

Finally, Morality had a significant main effect on error commission [$F(1, 44) = 5.96$, $p = .019$, $\eta^2 = .12$], such that participants made more errors while categorizing moral than immoral coworkers. The ANOVA also found a significant main effect of Congruence [$F(1, 44) = 7.44$, $p = .009$, $\eta^2 = .15$], with a higher number of errors occurring while participants were categorising incongruent coworkers. Another significant Morality x Congruence interaction effect was observed [$F(1, 44) = 7.96$, $p = .007$, $\eta^2 = .15$] indicating once again that the difference between congruent and incongruent CSs varied along with Morality, with a greater difference for moral coworkers. T tests confirmed that the difference between congruent and incongruent CSs reached significance for moral coworkers [$t(44) = 3.72$, $p = .001$, $d = .40$], but not immoral coworkers [$t(44) = .46$, $p = .65$].

3.2. Electrophysiological data

Grand average waveforms of neural correlates of both automatic (i.e. ΔERN) and conscious (i.e. ΔPe) performance monitoring ERPs are depicted in Figure 4 for all congruent and incongruent CSs. Consistent with our main hypothesis, analyses revealed that congruent CSs elicited on average higher amplitudes ΔERN than incongruent CSs [$t(30) = 2.54$, $p = .017$, $d = .26$], reflecting a diminished ability of the PM system to detect error commission while categorising incongruent CSs. However, contrary to our hypotheses, no difference emerged with regards with ΔPe [$t(30) = 1.22$, $p = .233$], suggesting a preserved ability to consciously appraise when a CS has been erroneously evaluated.

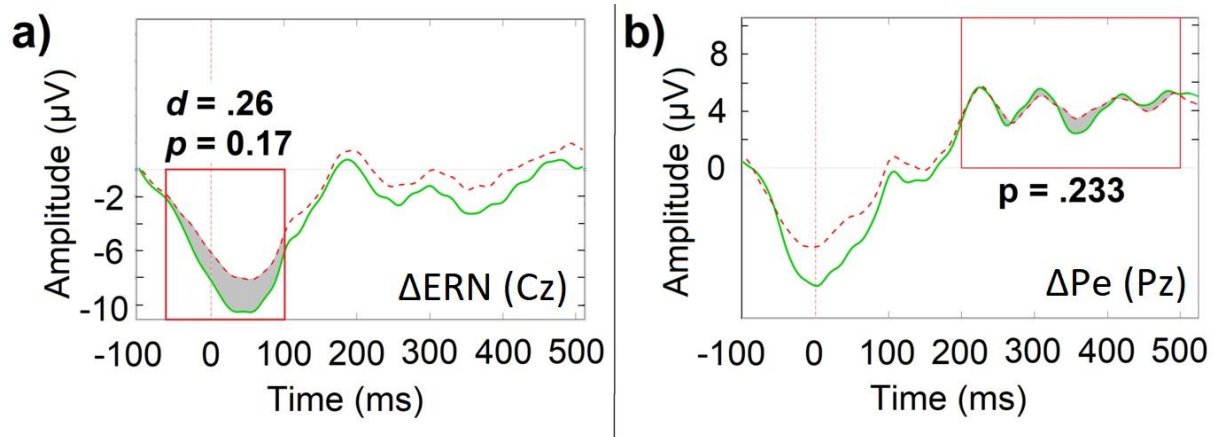


Figure 4. Grand average waveforms depicting (a) Δ ERN (electrode site Cz) and (b) Δ Pe (electrode site Pz). Solid green lines represent signal for congruent CSs, dashed red lines represent signal for incongruent CSs. Gray area under the curve represents the difference between congruent and incongruent CSs in terms of average error-related neural activity for the time period from (a) – 50 ms to 100 ms and (b) 200 ms to 500 ms. Statistical difference reached significance for the Δ ERN, while no significant difference emerged for Δ Pe.

Focusing on moral coworkers, analyses showed that congruent CSs were associated with significantly higher Δ ERN amplitudes when compared with their incongruent counterparts [$t(20) = 3.99, p = .001, d = .37$]. Once again however, no difference was observed between congruent and incongruent CSs with regards to Δ Pe [$t(20) = .23, p = .82$]. Interestingly, analyses revealed no significant difference between congruent and incongruent negative CSs in terms of Δ ERN amplitudes [$t(20) = .69, p = .497$], or Δ Pe amplitudes [$t(20) = .87, p = .393$], which shows that neither automatic error detection nor conscious appraisal of error commission were significantly altered by incongruence, as far as immoral coworkers are concerned.

4. DISCUSSION

The aim of this study was to explore the applicability of dual-process theories of attitude formation (Chaiken & Trope, 1999; Gawronski & Bodenhausen, 2006; Morewedge & Kahneman, 2010; Rydell & McConnell, 2006) to social evaluative conditioning (EC). Proponents of the propositional account of EC assume that EC is strictly mediated by the high-level, conscious, flexible processing of relational information between CSs and USs (De Houwer, 2007), whereas dual-EC theorists propose that a second set of associative processes also build evaluations in a parallel and automatic manner. Using an incongruent EC paradigm to condition either harmonious or conflicting attitudes toward fictive future coworkers (CSs), we hypothesised that attitudinal ambiguity would alter (1) perceived valence, (2) response times, (3) error commission, and (4) neural correlates of performance monitoring (PM). Confirming our first hypothesis, attitudinal ambiguity affected perceived valence of coworkers: despite clear instructions (both oral and written) not to account for the valence of USs (behaviours that were depicted as mere examples), participants still assimilated US valence to co-occurring individuals, resulting in more liking toward individuals paired with positive (i.e. moral) rather than negative (i.e. immoral) behaviours. These results replicate previous findings based on the incongruent EC paradigm (Elimari & Lafargue, 2023; Moran et al., 2015, 2016; Moran & Bar-Anan, 2013, 2020; Peters & Gawronski, 2011; Rydell & McConnell, 2006).

Behavioural performance was also affected by congruence: categorisation of congruent coworkers was associated with quicker RT and conveyed less errors than categorisation of incongruent coworkers. Interestingly, this effect emerged only for moral coworkers, while near identical RT and number of errors were observed for congruent and incongruent immoral coworkers. The present study paired behavioural data acquisition with electrophysiological data recording to assess how error-related negativity (ERN) and post-error positivity (Pe) behaved as a function of congruence. Our method allowed us to tap into neural responses to errors to infer how the brain evaluates CSs: since the PM system functions by detecting discrepancies between (1) intended and actual responses and (2) expected and actual outcomes, we argued that conditioning two antagonistic evaluations would (1) facilitate two mutually exclusive motor programmes and (2) build an incoherent set of post-response outcome predictions. We thus expected incongruence to be associated with an impaired ability of the PM system to detect errors as reflected in diminished ERN and Pe amplitudes. Confirming our hypothesis, errors were associated with decreased ERN amplitudes for incongruent CSs, suggesting a subpar automatic detection of error-conflict by the PM system. However, contrary to both our hypothesis and our previous results (Elimari & Lafargue, 2023), Pe amplitudes remained statistically equivalent regardless of congruence, suggesting a resistance of error awareness to incongruence. The fact that mere co-occurrences were enough to generate an attitudinal ambiguity that (1) influenced perceived valence, (2) slowed performance, (3) increased errors, and (4) altered neural correlates of PM, reinforces the idea that associative processes are at play in EC. Overall, our findings support dual-process theories of attitude formation (Gawronski & Bodenhausen, 2006; Morewedge & Kahneman, 2010; Rydell & McConnell, 2006) more than the propositional account (De Houwer, 2007).

4.1. Limitations: a case for a propositional account of the present results

We must however address three points that call for caution with regards to our conclusions. First, our study presents with some limits. For instance, we voluntarily limited the overall number of trials to a total of 400 trials in order to minimise the conditioning impact of the peeded Go/No-Go (that comprises repeated associations between stimuli and an overall valence-oriented purpose, e.g. “classify X stimulus as positive”). Consequently, the average number of relevant trials was 11.67 errors for congruent CSs and 14.3 errors for incongruent CSs. These numbers do not negate the validity of the present study, as previous work on ERN have for instance set 5 (Hajcak & Simons, 2008) or 6 (Olvet & Hajcak, 2009) relevant trials as the minimum number of errors. Nonetheless, future work should find ways to increase error commission while still minding the counter-conditioning effects of repeated categorizations. Another common issue with ERN studies is the focus on participants who displayed the worst performances. It is therefore unclear if the detectable effect of incongruence on neural responses would have been observed in individuals with highly accurate performances.

Secondly, our results repeatedly showed that the effect of congruence was moderated by Morality: differences in RT, errors, and ERN amplitudes between congruent and incongruent CSs only reached significance for positive stimuli. This can be explained by a heightened sensitivity of the associative system to negative valence: infusing a propositional positive attitude with an associative negative valence apparently results in much stronger attitudinal

ambiguity than vice versa. This valence-specific sensitivity of associative processes can be reconciled with the error-management theory (Haselton & Buss, 2000, 2009), which states that, under uncertainty, asymmetries in error-related fitness costs bias the brain into favouring lower-cost errors. Because misjudging an immoral person as moral inherently carries more risk than vice versa, the brain has presumably evolved to favour assumptions of malicious intents over assumptions of benevolent intents, thus leading to over-sensitivity of associative processes to negative valence. Nevertheless, it still remains that incongruence had no significant effect on half of the CSs pool. Though absence of proof is not proof of absence, the present data reinforce the propositional-EC account as far as negative CSs are considered.

A third point concerns the incongruent EC paradigm itself. Because propositions are heterogeneous and encompass both contrastive and assimilative relations, our procedure could have led in the incongruent condition to both “Paul is a nice person because he is neither aggressive nor dishonest” and “Paul reminds me of aggressivity and dishonesty”, i.e. that attitudinal ambiguity is to be ascribed to two evaluatively inconsistent propositional representations rather than two evaluatively inconsistent associative vs propositional representations (see Béna et al., 2022, for a similar conclusion). Consistent with this view, Bading and colleagues (2020) have provided evidence indicating flexible activations of propositional beliefs under varying conditions of automaticity, suggesting that EC might induce several independent but coexisting propositions with task-dependent degrees of availability. It could be, therefore, that our results do not dismiss propositional models as they can also account for attitudinal ambiguity. Obviously, this interpretation of the results raises further questions: why would a participant discard the only two propositions that make sense in the context of the task in favour of an alternative proposition? Is this alternative proposition produced instead or in parallel of the two well-established propositions of the task? Is this alternative proposition produced deliberately or uncontrollably? If the alternative proposition is produced both deliberately and instead of the two established/sensical ones, then the most obvious explanation is that participants sometimes depart from explicit instructions for unknown reasons.⁴ If so, simple assessments of the perceived validity (all propositions are by definition statements that carry a truth value) of a pool of potential propositions could help settle the matter. However, if the alternative proposition is built either uncontrollably, in a parallel fashion, or both, then one must consider the possibility of automatic propositional processes (see De Houwer et al., 2015 and Müller & Rothermund, 2019, for evidence of automatic activation of propositional beliefs).

One way through which automatic propositional EC could occur is the activation of pre-established propositions: a mind accustomed to the manipulation of a given proposition might be able to activate it without much need for conscious reasoning and could link a CS-US pair in a more sophisticated manner than “CS is associated with US” (see De Houwer, 2014, for a similar claim). Another way would be the activation of evolutionarily prepared relations that made sense in ancestral environments. One of the reasons we erred on the side of dual-process theories in our previous paper (Elimari & Lafargue, 2023) is the higher degree of consistency

⁴ Possibilities include misunderstanding of the instructions or active attempts to circumvent an assumed form of manipulation by the experimenter.

they display with evolutionary paradigms.⁵ It is however possible that before the advent of a high-order domain-general relational cognition (Holyoak & Lu, 2021), natural selection has driven the evolution of mechanisms prepared to process particular relations (e.g. “triggers/stops”, “attracts/repels”, “approaches/avoids”) in an automatic fashion. In other words, it might be that automatic EC is organized around propositional heuristics (subserved by the activation of (1) pre-established propositions or (2) evolutionarily prepared relations) rather than blind associations, which would mean that all EC processes (including those we share with non-human animals) are propositional by nature regardless of automaticity. To clarify, our claim is not that EC is never associative in nature (i.e. that EC never involves coactivation of nodes within a network of CS/US mental representations linked by edges that vary in associative strength, to use network theories lingo), but rather that even automatic EC might require the additional recruitment of nodes that specify relational information.⁶

A last point that is worth mentioning is the apparent resistance of error-awareness to attitudinal ambiguity: contrary to our previous findings (Elimari & Lafargue, 2023), Pe amplitudes were not significantly affected by incongruence in the present study. The most parsimonious explanation for that fact is replication failure. But the reason for this difference might also lie in the functional role of error-positivity, which is thought to reflect (1) error-awareness, (2) post-error correction, and/or (3) error significance (Endrass et al., 2005; Falkenstein et al., 2000; Leuthold & Sommer, 1999; Nieuwenhuis et al., 2001; Overbeek et al., 2005). Since our precedent study used semantic stimuli, it might be that social EC differs from other forms of EC because social judgments were so crucial for fitness that the brain evolved to correct and compensate for erroneous social inferences in earlier processing stages. This claim is consistent with social origin theories of human intelligence (Dunbar, 1998; Dunbar & Shultz, 2007; Gavrilets & Vose, 2006; Holloway, 1967; Humphrey, 1976) that assume the intrinsically high-order cognitive nature of social processes: the high-level components of PM (i.e. error-awareness) might therefore be optimized to quickly solve social attitudinal ambiguity better than other forms of ambivalence. To be clear, we do not state that reading is not a high-order cognitive activity. However, while social stimuli (i.e. conspecifics) inherently carry a great deal of evolutionary significance and trigger domain-specific mechanisms (i.e. processes that have specific input criteria for activation), semantic stimuli (i.e. words) are arbitrary creations of humankind that have next to no meaning on their own. As a way to assess this claim, we visually explored differentials in topographical patterns of neural activity for both social (present study) and nonsocial (Elimari & Lafargue, 2023) stimuli processing: while neural activity is rather similar in the first stages of error-detection, two easily observable specificities emerge during the error-awareness stages for social stimuli with (1) a large negative frontal wave and (2) an expansion of the Pe component to occipital and temporal sites (Figure 5). Future work is needed to determine the exact underpinnings of these domain-specific neural patterns but they might

⁵ The claim that evaluative conditioning is strictly mediated by high-order, conscious, deliberative reasoning about complex relations would imply both the emergence of such function in late hominins and the impossibility to condition evaluations in animals.

⁶ Obviously, our claim implies the possible but optional (i.e., pre-conscious) availability of the mental statement that several authors associate with propositional thinking. We speculate that such implication might lead these authors to qualify the automatic processes we describe here as non-propositional but merely relational.

reflect the recruitment of a larger network of neural structures to compensate for the shortcomings of early automatic error-detection when social information is processed.

2D REPRESENTATION OF THE AVERAGE ERROR-RELATED SIGNAL FOR:

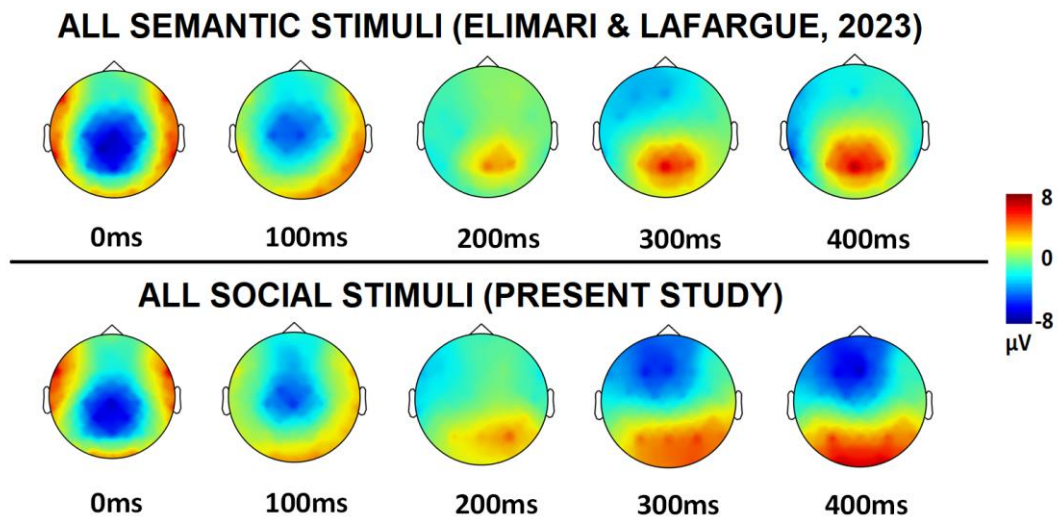


Figure 5. 2D topographical representation of grand-average error-related signals for all semantic stimuli (Elimari & Lafargue, 2023) and all social stimuli (present study). Despite similar activity of early-stage processing, domain-specific neural patterns arose for social stimuli with an error-awareness signal that spread to occipital and temporal sites, as well as a clear post-ERN negative centro-frontal wave. These differences might reflect additional processes of post-error compensation for social evaluations subserved by large-scale fronto-parietal connectivity.

But domain-specificity might have implications that go beyond differentials in error-awareness as a function of stimulus nature. Evolutionary psychologists traditionally adhere to the view that, though the human brain is equipped with domain-general high-order mechanisms, a mind fine-tuned by natural selection to solve adaptive problems is likely to be more effective if it predominantly rests on a large number of domain-specific mechanisms rather than one or few domain-general ones (Barrett & Kurzban, 2006, 2012; Cosmides & Tooby, 1992, 1997). From a dual-process standpoint, it implies a vast asymmetry in the number of processes involved in EC, with automatic EC being subserved by a vast array of specialised modules (i.e. that process a narrow set of inputs to produce a restricted number of fitness-enhancing outputs), while propositional EC is ultimately carried out by a small number of high-order, domain-general, controlled processes. Following these assumptions, the question “What are the processes that subserve automatic EC?” might require a more detailed and complete response than “Automatic EC stems from associative processes”. For instance, the behavioural immune system (i.e. a set of psychological mechanisms promoting disease-avoidance) biases human and non-human animals into evaluating negatively and avoiding potential pathogen vectors such as rotten food, corpses, or ill individuals (Ackerman et al., 2018; Schaller & Duncan, 2007; Schaller & Park, 2011). Another example is the specialised social bargaining system involved in the production of anger-mediated attitudes toward individuals who serve their interests at the expense of one’s own welfare (Sell et al., 2009). Both neurocognitive systems manufacture attitudes that are

likely to be mediated by associative processes (e.g. the behavioural immune system processes associations between individuals and signs of infection such as cough, rashes, or blisters), but both systems manage different threats via the emergence of distinct attitudinal, affective, cognitive, and behavioural outputs. Therefore, associative processes could simply be a shared feature of a large organised system of processes participating in attitudinal cognition. Moreover, going back to our earlier claim that even automatic EC might require the additional recruitment of nodes that code for relational information within a network of CS/US representations, we propose that contextual information that has evolutionary relevance could lead to the automatic recruitment of specific “relational nodes” that ultimately guide attitude formation in a way that motivates adaptive behavioural responses. We believe that future research on EC should integrate principles from evolutionary psychology and investigate how evaluative responses vary as a function of evolved processes at play.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORCID

Nassim Elimari <http://orcid.org/0000-0003-2787-2725>

Gilles Lafargue <http://orcid.org/0000-0003-4905-6518>

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