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**IMPACT STATEMENTS:** Although the real-life environment is often dynamic and looming affective stimuli seem critical for survival, little is known about their effect on endogenous attention. We explored the combined effect of realistic (3D) looming motion and emotion on endogenous attention, demonstrating the progressive inclusion of negative stimuli in the attentional focus is produced earlier in dynamic (P2p) than in static versions (LPP).

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## **Realistic (3D) looming of emotional visual stimuli: attentional effects at neural and behavioral levels**

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## **Abstract**

Previous research shows that endogenous attention (the controlled selection of certain aspects of our environment) is enhanced towards emotional stimuli due to its biological relevance. Although looming affective stimuli such as threat seem even more critical for survival, little is known about their effect on endogenous attention. Here we recorded neural (event-related potentials, ERPs) and behavioral responses (errors and reaction times) to explore the combined effect of emotion and looming motion. 3D-recreated static and moving animals assessed as emotionally positive, negative and neutral, were presented to participants (n=71), who performed an indirect categorization task (vertebrate vs. invertebrate). Behavioral results showed better task performance, as reflected by lower number of errors and reaction times, in response to threatening stimuli. Neural indices revealed significant early (P1p, 150 milliseconds), intermediate (P2p, 240), and late (LPP, 450) effects, the latter being more intensely associated with behavior, as revealed by regression analyses. In general, neural indexes of attention to both static and dynamic stimuli showed a positivity offset in early stages and a negativity bias in subsequent phases. However, and importantly, the progressive inclusion of negative stimuli in the attentional focus is produced earlier in the case of dynamic (at P2p latency) than in static versions (at LPP). These results point to an enhancement of attention, particularly in temporal terms, towards stimuli combining motion and biological significance.

**Keywords:** Endogenous attention, ERPs, 3D, looming motion, emotion

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## 1. Introduction

Attentional mechanisms allow the nervous system to select relevant stimuli of the environment to be subsequently processed and filter out irrelevant stimuli (Allport, 1989). Attention is often divided into endogenous, also known as top-down or controlled, which enable the voluntary and conscious selection of relevant information of the environment, and exogenous, also termed bottom-up or automatic, which consists in the involuntary capture of our attentional focus by salient or novel stimuli (Carretié, 2014; Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002; Posner & Petersen, 1990). Endogenous attention, which is the type explored here, has also been favored by evolution to preferentially focus on, and increase towards, biologically relevant stimuli, which are, by definition, emotional (Lang, Bradley, & Cuthbert, 1997). Indeed, behavioral research has consistently shown that affective content of visual stimulation such as scenes or faces modulates task performance in endogenous attention tasks. These tasks often consist of stimulus categorization paradigms, and results differ as a function of whether the emotion is task-relevant or not (direct and indirect tasks, respectively). Concretely, in direct tasks (e.g., categorizing the emotional content of a visual scene), negative stimuli improve performance by eliciting faster reaction times and lower error rates than neutral (Del Zotto & Pegna, 2015; Hajcak, Moser, & Simons, 2006; Rigoulot et al., 2011; Yuan et al., 2014). However, negative stimuli worsen performance –as reflected in slower reaction times and higher error rates- in indirect tasks (e.g., categorizing whether the image corresponds to an indoor or outdoor scene) (De Cesare & Codispoti, 2006; Hajcak & Nieuwenhuis, 2006; Lichtenstein-Vidne, Henik, & Safadi, 2012).

Evidence of endogenous attention bias towards emotional stimuli has been also provided by electrophysiological data. In particular, event-related potentials (ERPs) are especially useful to disentangle rapid attention-related neural processes and subprocesses that cannot be distinguished behaviorally. Several ERP components have been postulated to reflect endogenous attention processes, such as P1 (Anllo-Vento, Luck, & Hillyard, 1998; Luck, Heinze, Mangun, & Hillyard, 1990; Martínez, Di Russo, Anllo-Vento, & Hillyard, 2001; Zhang & Luck, 2009), N1 (Di Russo, Martinez, & Hillyard, 2003; He, Fan, Zhou, & Chen, 2004; Martínez et al., 2006), P2 (Luck &

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Hillyard, 1994; Luck & Kappenman, 2012; Wijers, Mulder, Gunter, & Smid, 1996), or late positivities (LPP) (Anllo-Vento & Hillyard, 1996; Luck & Kappenman, 2012; Polich, 2007). Importantly, all these components show greater amplitudes in response to attended emotional visual stimuli than to neutral: P1 (Alorda, Serrano-Pedraza, Campos-Bueno, Sierra-Vázquez, & Montoya, 2007; Recio, Sommer, & Schacht, 2011; Smith, Cacioppo, Larsen, & Chartrand, 2003), N1 (Carretié, Hinojosa, López-Martín, & Tapia, 2007; Foti, Hajcak, & Dien, 2009; Keil, Bradley, Hauk, Rockstroh, Elbert, & Lang, 2002), P2 (Carretié, Mercado, Tapia, & Hinojosa, 2001a; Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Lu, Jaquess, Hatfield, Zhou, & Li, 2017), and LPP (Carretié, Hinojosa, Albert, & Mercado, 2006; Delplanque, Silvert, Hot, & Sequeira, 2005; Foti et al., 2009; Hajcak, Dunning, & Foti, 2007; Pourtois, Schettino, & Vuilleumier, 2013). In general, ERP components under 300ms latency (P1, N1, P2) appear to be sensitive to emotional valence, showing enhanced amplitudes to negative stimulation, whereas LPP shows an enhanced amplitude towards arousing stimuli, both positive and negative (see Olofsson, Nordin, Sequeira, & Polich, 2008 for a review).

Another stimulus characteristic that modulates endogenous attention is motion. At the behavioral level, results point to faster and more accurate responses to motion directions in a motion-dominant task (Nobre, Rao, & Chelazzi, 2006). Also, Martín-Loeches and colleagues (1999) found that stimuli presented in motion (in addition to other characteristics as color) were responded faster compared to those motionless. At the ERP level, endogenous attention to motion is reflected in the early P1 and N1 components (Anllo-Vento & Hillyard, 1996; Coch, Skendzel, Grossi, & Neville, 2005; Karayanidis & Michie, 1997; Martín-Loeches, Hinojosa, & Rubia, 1999) and in later modulations such as the selection positivity (SP) and the selection negativity (SN), elicited during the interval 160-350 ms after stimulus onset (Beer & Röder, 2004; Hillyard & Anllo-Vento, 1998; Martín-Loeches, Hinojosa, & Rubia, 1999). Additionally, distinct types of motion modulate attention differently. Delon-Martin and colleagues (2006) showed that in-depth motion (expansion and contraction) is processed differently than in-plane motion (horizontal translation and rotation). In depth motion elicited enhanced amplitudes of P2 and N2 components compared to in-plane motion and, regarding the former, expansion motion showed greater P2 amplitudes than contraction (Delon-

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Martin et al., 2006). These results point to a differentiated processing of each type of motion, shedding light on the special status of expansion or looming motion. Our research focuses on looming motion since it is often associated with warning of imminent danger or collision, and hence with greater urgency for action (Billington, Wilkie, Field, & Wann, 2011; Holliday & Meese, 2005).

The confluence of motion and emotion would, in theory, further increase their separate capability to enhance endogenous attention. Although real-life environment is often dynamic, the vast majority of emotional research employs static images in experimental tasks targeting endogenous attention. However, some clues point to an enhanced endogenous attention towards dynamic emotional stimuli. First, some theoretical proposals postulate that the human visual system has a default priority setting for dynamic events indicating a potential threat (Lin, Franconeri, & Enns, 2008). This type of motion is often associated with the warning of imminent danger (Franconeri & Simons, 2003, 2005; Lin, Franconeri, & Enns, 2008) and needs processing of maximal priority (looming events presented on a collision path need for imminent action, acts as a potential caveat that urges for action). Second, behavioral studies on facial expressions show how dynamic faces are better recognized (Ambadar, Schooler, & Cohn, 2005; Harwood, Hall, & Shinkfield, 1999; Recio, Sommer, & Schacht, 2011) and receive higher arousal ratings (Biele & Grabowska, 2006; Weyers, Mühlberger, Hefe, & Pauli, 2006) than static, arguing for greater emotional facilitation in the former case (Sato et al., 2004). And third, behavioral data on non-facial dynamic emotional scenes showed also enhanced attention with a clear bias towards threatening stimuli. Vagnoni and collaborators (2012) used approaching threatening (snakes and spiders) and non-threatening (butterflies and rabbits) stimuli to investigate whether the looming threat content affects the perceived time-to-collision (TTC). Looming motion was recreated via bidimensional expansion (size increase) of stimuli, and participants were asked for TTC estimation. Whereas threatening and non-threatening stimuli “approached” at the same speeds, authors found shorter TTCs for looming threatening stimuli (i.e., threatening stimuli were judged as colliding sooner than non-threatening stimuli). Using a categorization paradigm, Sagliano and collaborators (2014) employed an indirect task, asking participants whether certain stimuli were living or non-living beings, and a direct task, asking to judge the threat degree in an

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apparent motion paradigm (also, in this case, approach or receding were emulated by bidimensional manipulation of stimulus size). They found that approaching threats were explicitly evaluated as more threatening and elicited more freeze-like responses (operationalized as slower reaction times) compared to receding threats.

To the best of our knowledge, only one electrophysiological study on the interactions between emotion and motion has focused on this issue. Vagnoni and colleagues (2015) gave continuity to the behavioral experiment conducted in 2012 and analyzed both ERPs (amplitudes) and time-frequency dynamics. These authors did not report any interaction between motion and emotion, but several interesting main effects were found. Regarding motion, ERP results showed that as the speed of looming increased, parietal N1 amplitude and the spectral power of the beta band also increased. Concerning emotion, threat increased the amplitude of frontal and occipital N1 and LPP components and also enhanced the spectral power of the alpha and high gamma bands. These results are interpreted in terms of increased attention towards emotional stimuli (Vagnoni, Lourenco, & Longo, 2015). In our opinion, the incipient study of the neural activity underlying endogenous attention to stimuli combining motion and emotion would significantly benefit from additional exploration to complement these valuable data. For example, presenting emotional stimuli that differ in valence would be of maximal interest to test whether motion affects differentially to negative and positive stimuli. Additionally, a relevant issue in this field is the use of realistic/naturalistic looming motion. In the latter regard, and as far as we know, only bidimensional (2D) motion recreation has been employed - by changing the location or size of stimuli- both in behavioral and ERP research. The use of 3D stimulation provides more realistic experiences (Riva et al., 2007), especially relevant for the study of looming motion effects. Also, 3D stimulation effectively limits the influence of external distraction, engaging selective attention more effectively than traditional 2D methodology (Li et al., 2020).

Therefore, our scope was to characterize, both behaviorally and through ERPs, the endogenous attention to visual stimuli varying with respect to their emotional load. Thus, static and looming animals presenting negative, positive, and neutral valence were presented using 3D motion recreation and an indirect task. Animals are an optimal choice (Vagnoni et al., 2012, 2015), since they



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may be static or moving in natural situations. Some animals tend to be commonly perceived as threatening (e.g., snakes or spiders) and others as non-threatening, including neutral (e.g., fishes or birds) or positive animals (e.g., rabbits or puppies) (EmoMadrid: Carretié, Tapia, López-Martín, & Albert, 2019; GAPED: Dan-Glauser & Scherer, 2011; IAPS: Lang, Bradley, & Cuthbert, 2005). We hypothesize, mainly taking into account the proposals linking looming and urgency mentioned above, that endogenous attention to visual stimuli will be maximal towards stimuli presenting concurrently both motion and threatening properties. This pattern would be reflected as enhanced performance in the indirect task (animal categorization) and greater amplitudes in at least one of the early or late ERP components indexing endogenous attention described above.

## **2. Method**

### 2.1. Participants

Seventy-four healthy volunteers participated in the study, although data from only seventy-one of them were analyzed, as explained later (57 women; age range = 18-31, mean = 19.64 years, SD = 2.14 years). This sample size gave us an optimal statistical power ( $1-\beta = 0.80$ ) even to reliably detect small effects ( $\eta^2p = 0.10$ ) for the more restrictive main effect involving the two-level factor (Motion) in a 2x3 ANOVA design. All power calculations were computed using the MorePower 6.0.4 calculator (Campbell & Thompson, 2012). The study was previously approved by the Universidad Autónoma de Madrid's ethics committee. All participants were students of Psychology at this university. They provided their informed consent and received academic compensation for their participation.

### 2.2. Stimuli and procedure

The experiment was conducted inside an electrically shielded, sound-attenuated room. Participants' face position was 100 cm from the stimulation screen. Stimuli were presented on a ViewPixx© screen using Psychtoolbox 3 task programming extensions for Matlab (Brainard, 1997). The stimuli were computer-generated pictures developed by an expert in graphic design in such a way that they could be perceived stereoscopically, as explained later. Dynamic and static stimuli –looming motion clips or a single photogram, respectively-, consisted of emotionally threatening (a spider or a snake), positive (a

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ladybird or a frog), and neutral animals (a bird or a butterfly), and may be visualized at <https://goo.gl/kaNgCG>. These stimuli were selected from a wider set of animals (that included wasps, ants, and fishes, see Table 1) as a function of their Valence and Arousal ratings provided by an independent sample of 94 healthy volunteer students from the Universidad Autónoma de Madrid. As indicated below, the selection was confirmed as adequate after the emotional ratings provided by the experimental sample. Consequently, six conditions were implemented: threatening dynamic (dNeg), threatening static (sNeg), positive dynamic (dPos), positive static (sPos), neutral dynamic (dNeu) and neutral static (sNeu). The emotional load of stimuli was determined through a previous questionnaire which is described below. The total set of 384 trials (64 per condition) was displayed randomly and separated into three blocks of 128, so participants had two rest periods of approximately 3 minutes each. The endogenous attention task consisted in categorizing the animal depicted in each trial as vertebrate or invertebrate by pressing two different keys. Half of the stimuli of each condition were vertebrate and the other invertebrate and the key-response assignment was counterbalanced across participants. The task was indirect (i.e., not directed to categorize motion or emotion) in order to avoid the “relevance-for-task effect”, a cognitive bias that leads the participant to consider some stimuli as more important for the task than others (Duncan-Johnson & Donchin, 1977).

Furthermore, with the aim of increasing ecological validity, all stimuli were presented in 3D on a ViewPixx© screen through a 3DPixx LCD with shutter glasses that occluded one eye at a time, 60 times/second per eye, in congruence with the refresh rate of the monitor (120 Hz). This setting led the participant to perceive the image in a three-dimensional space (in front of and behind the actual screen plane), as a result of a slightly horizontally shifted perspective in the images projected to the left and right eyes. In order to select participants, an initial test to ensure that 3D vision was indeed achieved through the LCD glasses was carried out by presenting a picture different from those employed in the experimental run. All participants reported 3D vision through the LCD glasses. In dynamic stimuli (always presenting a looming motion, as indicated), the area of the biggest animal in figure-ground terms (i.e., the spider) – oscillated between  $3.44^\circ \times 5.72^\circ$  (wide) in the “farthest” position and  $6.30^\circ \times 9.72^\circ$  in the “closest”, and in the case of the smallest animal (ladybird), the area

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rank was  $1.72^\circ \times 2^\circ$  to  $3.44^\circ \times 2^\circ$ . These differences regarding sizes were not significant, neither the width nor the height of the images [S-W test of normality:  $W(24) = 0.894$ ,  $p = 0.016$ ; Kruskal-Wallis's test on the "farthest" position: Width  $\chi^2(2) = 1.143$ ;  $p = 0.565$ , and Height  $\chi^2(2) = 4.191$ ;  $p = 0.123$ , and in the "closest" position: Width  $\chi^2(2) = 2.000$ ;  $p = 0.368$ , and Height  $\chi^2(2) = 3.603$ ;  $p = 0.165$ ]. The main path of all animals was always rectilinear towards the participant and crossed the fixation (foveal) point, a yellow dot ( $0.23^\circ \times 0.23^\circ$ ) located on the center of the screen. The static stimuli were always centrally presented and consisted of the frame (or photogram) of each clip in which the corresponding animal was in the midpoint of the path. The area of the biggest animal in figure-ground terms (the spider, as indicated) in the static condition was  $3.44^\circ \times 6.87^\circ$ , and for the smallest animal (ladybird) was  $2.29^\circ \times 2.29^\circ$ . Both dynamic and static stimuli were showed on a plain black background. Since these same stimuli were also presented in an exogenous attention task described elsewhere, stimuli included two yellow lines ( $3.15^\circ \times 0.57^\circ$  wide each line) presented in the periphery at both sides of the screen ( $9.8^\circ$  from their center to the middle of fixation dot). These lines were irrelevant for the task and were exactly the same for all conditions (dNeg, sNeg, dPos, sPos, dNeu, sNeu).

As shown in Figure 1, each trial started with the presentation of the fixation dot for 300 ms, followed by a dynamic or static stimulus for 800 ms. Thereafter, a fixation point appeared during 1200 ms. Participants were instructed to continuously fixate their gaze at the fixation dot and to avoid blinking during stimulus presentation. A practice block of 20 trials presenting static animals different from those employed in the experimental run was previously administered. After completing the experimental run, all participants evaluated the stimuli employed in the task in terms of Valence and Arousal in a Likert scale from 1 (very negative/very relaxing) to 5 (very positive/very arousing). The results of this affective evaluation were submitted to Friedman's non-parametric tests since they did not achieve normality [K-S tests:  $D(426) = 0.158$  and  $0.177$  in Valence and in Arousal dimensions respectively,  $p < 0.001$  in both cases]. As Table 2 shows, results followed the expected pattern: all conditions differed from each other in the Valence dimension showing a Pos>Neu>Neg pattern [Friedman's test on Valence:  $\chi^2(2) = 90.300$ ;  $p < 0.001$ , and pairwise Wilcoxon signed rank test for

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Pos vs. Neg:  $Z = -7.057$ ,  $r = 0.592$ ; Pos vs. Neu:  $Z = -5.226$ ,  $r = 0.438$ , and for Neu vs. Neg:  $Z = -5.834$ ,  $r = 0.489$ ,  $p < 0.001$  in all cases], whereas in the Arousal dimension there were no differences between Neu and Pos but both differed from the Neg condition, rated as the most arousing condition (Neg > Pos/Neu) [Friedman's test on Arousal:  $\chi^2(2) = 53.139$ ;  $p < 0.001$ , and pairwise Wilcoxon signed rank test for Pos vs. Neu:  $Z = -1.190$ ,  $p = 0.234$ ,  $r = 0.100$ ; Pos vs. Neg:  $Z = -5.817$ ,  $p < 0.001$ ,  $r = 0.488$ , and for Neu vs. Neg:  $Z = -5.300$ ,  $p < 0.001$ ,  $r = 0.445$ ] (see Table 2). In order to prevent potential perceptual biases, we measured the luminosity mean of each picture with Adobe Photoshop© CC 2015. This measure yielded a homogeneous luminosity for the picture set, as the maximal difference between the six conditions was 0.48% of the total range of luminance (defined here as the luminance emitted by a white screen minus the luminance emitted by a black screen): see Table 2.

\*\*\* Table 1, Table 2 and Figure 1 about here \*\*\*

### 2.3. Recording and preprocessing

Electroencephalographic (EEG) activity was recorded using an electrode cap (ElectroCap International) with tin electrodes. Fifty-nine electrodes were placed at the scalp following a homogeneous distribution (International 10-20 System) and referenced to the nose tip.

Electrooculographic (EOG) data were recorded supra- and infra-orbitally (vertical EOG) as well as from the left versus right orbital rim (horizontal EOG). The recordings were digitized at a sampling rate of 420 Hz with an online analog bandpass filter of 0.3 Hz to 10 kHz. The continuous recording was divided into 1000 ms epochs for each trial, beginning 200 ms before the stimulus onset.

Behavioral activity was recorded through a numeric keypad. Outlier trials (with responses before 250 ms or after 2000 ms) were eliminated. An offline digital bandpass filter of 0.3 to 30 Hz was applied using Fieldtrip software ( <http://fieldtrip.fcdonders.nl>; Oostenveld, Fries, Maris, Schoffelen, 2011).

Ocular artifact removal was carried out through an Independent Component Analysis based strategy (Jung et al., 2000a) as implemented in Fieldtrip. This strategy is widely used to effectively detect, separate, and remove ocular artifacts and is favorably compared to the results obtained using rejection or regression methods (Jung et al., 2000b). After this process, the second stage of visual inspection of EEG data was conducted. If any further artifact was present, the corresponding trial was

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discarded. This procedure led to the average admission of 55.68 (SD=6.07) dNeg trials, 54.37 (6.07) sNeg, 54.82 (7.20) dPos, 55.06 (6.26) sPos, 55.21 (6.11) dNeu and 54.69 (6.46) sNeu, with the difference among conditions being non-significant [K-S test:  $D(426) = 0.129$ ,  $p < 0.001$ ; Friedman's test:  $\chi^2(5) = 10.756$ ,  $p = 0.056$ ]. The minimum number of trials accepted for averaging was 35 per participant and condition. Three of the original 74 participants were discarded from the analysis: two of them due to an excessive number of interferences (noisy channels were recovered through interpolation from neighbor electrodes only if they represented up to 10% of total number of electrodes, a limit surpassed in these two cases) and the remaining participant due to technical failures in the presentation of stimuli. Besides this correction and rejection strategies, additional analyses were carried out in order to discard any significant influence of ocular activity in the observed results. To that aim, repeated-measure analyses of variance (ANOVAs) introducing Motion (dynamic, static) and Emotion (threatening, positive, neutral) as factors were performed on both horizontal and vertical EOG original data and, in case any difference was observed, this ocular activity was neutralized as explained next.

## 2.4. Data analysis

### *2.4.1. Detection, spatiotemporal characterization, and quantification of relevant ERP components*

Detection and quantification of the relevant early (P1, P2, and/or N1) and late ERP components (LPP) described in the Introduction were carried out through a covariance-matrix-based temporal PCA (tPCA), a strategy that has repeatedly been recommended for these purposes (e.g., Chapman, Hoag, & Giaschi, 2004; Dien, 2010). In brief, tPCA computes the covariance between all ERP time points, which tends to be high between those involved in the same component and low between those belonging to different components. Once quantified in temporal terms, the topography at the scalp level of these components was decomposed into its main spatial regions via a spatial PCA (sPCA) performed on temporal factor (TF) scores. sPCA provides, for each TF, a reliable division of the scalp into different regions or spatial factors (SFs). Basically, each SF is formed with the scalp points where recordings tend to covary. Temporal and spatial factor scores are the parameters in which TFs and SFs can be quantified and are linearly related to amplitudes. The decision on the number of factors to

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select both in tPCA and sPCA was based on the scree test (Maxwell & Cliff, 2006). Extracted factors were submitted to promax rotation with a kappa value of 3, as recommended (Dien, 2010).

#### *2.4.2. Analyses on experimental effects*

With respect to ERPs, since ocular showed some significant differences between conditions, and despite ocular activity was subtracted from ERPs using ICA and epoch revision/rejection as explained above, the experimental effects were analyzed via analysis of covariance (ANCOVA) in order to partial out its possible influence. Thus, factor scores (linearly related to amplitudes, as explained) were submitted to repeated-measures ANCOVA introducing Motion (dynamic - d-, static – s-) and Emotion (threatening - Neg-, positive - Pos-, neutral - Neu) as factors (results are also shown in Table 4), plus hEOG and vEOG data as covariates. The analyses were carried out using the SPSS 20.0 software package (IBM SPSS Inc, 2011).

With respect to behavior, average reaction times (in milliseconds) and number of errors (defined here as average sum of incorrect and blank responses) for each participant in each condition were submitted to non-parametric contrasts, due to non-Gaussian distribution [K-S test on reaction times:  $D(426) = 0.110, p < 0.001$ ; on number of errors:  $D(426) = 0.213, p < 0.001$ ]. Therefore, both variables were submitted, separately, to Friedman's test on Motion (dynamic, static) and Emotion (threatening, positive, and neutral), and post-hoc pairwise comparisons were carried out with the Wilcoxon signed-rank test. Effect sizes in these Wilcoxon contrasts were computed using the procedure described by Pallant (2007, pp. 224-225) for this non-parametrical test. Means and standard deviations of behavioral data are presented in Table 3.

\*\*\* Table 3 about here \*\*\*

In addition, three robust regression analyses, recommended over standard parametric (least squares) linear regression when cases do not fit Gaussian distributions (Huber, 1972), were carried out to explore the following relationships: i) behavior (reaction times and number of errors) and the amplitude of relevant ERP components, ii) emotional assessments (Valence and Arousal) and these amplitudes, and iii) behavior and emotional assessments. We employed an iterative reweighted least

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squares estimation as implemented in the RLM procedure available within the MASS package (Ripley et al., 2016) for R (R Core Team, 2017) using the Huber weights (Huber & Wiley, 1981). The first two robust regression analyses were carried out for each component introducing their amplitudes as dependent variables, whereas the independent variables were reaction times and errors in one analysis and Valence and Arousal in the other. In the third regression analysis, we introduced reaction times and errors as dependent variables (separately) and Valence and Arousal as independent variables.

### 3. Results

#### 3.1. ERP data: P1, P2, and LPP

Figure 3 shows a selection of grand averages after subtracting the baseline activity (200 ms before stimulus onset) from each ERP. These grand averages correspond to parietal and occipital channels, where significant results are more evident. As indicated in the Methods, the first step was detecting and quantifying the relevant ERP components in the temporal domain through a tPCA. As a consequence, six temporal factors (TFs) were extracted and submitted to promax rotation. As Figure 2 shows, three of them (mentioned in the introduction) correspond to the components of interest based on their factor peak latency and topography: TF5 (~ 150 ms), TF4 (~ 240 ms), and TF1 (~ 450 ms), associated to P1, P2, and LPP, respectively (N1 is the only ERP component described in the Introduction as indexing endogenous attention which was not detected by tPCA). These labels will be employed hereafter to make results easier to understand. The second step, as also indicated, was applying a sPCA to each temporal component in order to disentangle their spatial distribution. As a consequence, P1, P2, and LPP were decomposed into two SFs each, one anterior and other posterior in all cases.

\*\*\* Figure 2 and Table 4 about here \*\*\*

#### *3.1.2. Experimental effects on ERP components*

Table 4 shows the mean and standard deviation of all SF scores (equivalent to amplitudes, as indicated) corresponding to P1, P2, and LPP in each experimental condition. As mentioned in the Methods section, we analyzed possible ocular activity differences among conditions via ANOVA, introducing Motion (dynamic, static) and Emotion (threatening, positive, and neutral) as factors on

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vertical EOG (vEOG) and horizontal EOG (hEOG) data. With respect to the time window corresponding to *early* EPR effects –100 to 300 ms-, no significant differences were observed in hEOG, whereas vEOG differed with respect to Motion [hEOG: Emotion:  $F(2,140) = 2.246, p = 0.110, \eta^2p = 0.031$ ; Motion:  $F(1,70) = 2.182, p = 0.144, \eta^2p = 0.030$ ; Interaction:  $F(2,140) = 0.052$ ; Greenhouse-Geisser  $\epsilon$  (0.952) corrected  $p = 0.943, \eta^2p = 0.001$ ; vEOG: Emotion:  $F(2,140) = 2.861, p = 0.061, \eta^2p = 0.039$ ; Motion:  $F(1,70) = 20.077, p < 0.001, \eta^2p = 0.223$ ; Interaction:  $F(2,140) = 0.004, p = 0.996, \eta^2p = 0.000$ ]. Moreover, *late* window –from 300 to 600 ms- also showed a significant difference in both hEOG and vEOG with respect to Emotion [hEOG:  $F(2,140) = 19.663$ ; GG (0.954) corrected  $p < 0.001, \eta^2p = 0.219$ ; vEOG:  $F(2,140) = 4.831, p = 0.009, \eta^2p = 0.065$ ] and Motion [hEOG:  $F(1,70) = 4.016, p = 0.049, \eta^2p = 0.054$ ; vEOG:  $F(1,70) = 4.929, p = 0.030, \eta^2p = 0.066$ ], but not to their interaction [hEOG:  $F(2,140) = 1.661$ , GG (0.930) corrected  $p = 0.196, \eta^2p = 0.023$ ; vEOG:  $F(2,140) = 1.169, p = 0.314, \eta^2p = 0.016$ ].

Therefore, as also indicated in Methods, factor scores were submitted to repeated-measures ANCOVAs. The spatial factors reflecting the experimental effects were SF2 for P1 and P2 components, and SF1 in the case of LPP, in the three cases presenting a parieto-occipital topography. Therefore, we will label these spatial components as P1p and P2p ('p' from posterior; LPP usually presents posterior topography).

*P1p (TF5; peak at 150 ms).* ANCOVAs on SF2, distributed over a parieto-occipital bilateral scalp region (Figure 3a), yielded a significant main effect of Emotion [ $F(2,341) = 3.152, p = 0.044$ ]. Post-hoc tests showed that Pos elicited greater amplitudes than Neu ( $p = 0.027$ ), being the rest of contrasts non-significant (all  $p > 0.091$ ). We also found a significant main effect of Motion [ $F(1,351) = 15.464, p < 0.001$ ], where dynamic stimuli showed greater amplitudes than static. We did not find a significant interaction between Emotion and Motion [ $F(2,341) = 2.497, p = 0.084$ ].

*P2p (TF4; peak at 240 ms).* Results on SF2, with a parieto-occipital bilateral distribution (Figure 3b), revealed a significant main effect of Emotion [ $F(2,340) = 13.372, p < 0.001$ ]. Post-hoc tests revealed that Pos elicited greater amplitudes than Neg and Neu ( $p < 0.001$  in both cases), and no differences were found between the latter two ( $p = 1.000$ ). The main effect of Motion also reached



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significance [ $F(1,347) = 88.131, p < 0.001$ ], P2p amplitudes being greater for static than for dynamic stimuli. The interaction between Emotion and Motion was also significant [ $F(2,339) = 7.734, p < 0.001$ ] and post-hoc comparisons showed the following results: i) within static conditions, sPos trials elicited greater amplitudes than sNeg and sNeu ( $p < 0.001$  and  $p = 0.002$ , respectively) and also sNeu presented greater amplitudes than sNeg ( $p = 0.021$ ), showing a sPos>sNeu>sNeg pattern, and ii) within dynamic conditions, dPos and dNeg elicited greater amplitudes than dNeu ( $p = 0.002$  and  $p = 0.047$ , respectively), being the comparison between dPos and dNeg non-significant ( $p = 0.878$ ). The rest of relevant pairwise contrasts were not significant.

*LPP (TF1; peak at 450 ms)*. Results on SF1 revealed a significant main effect on Emotion [ $F(2,342) = 23.882, p < 0.001$ ] at the parieto-occipital bilateral scalp region (Figure 3c). Post-hoc tests revealed that Neg stimuli elicited greater amplitudes than Pos and Neu, and that the two latter also differed, showing a Neg > Pos > Neu pattern ( $p < 0.001$  in all cases). The main effect of Motion did not reach significance ( $p = 0.059$ ). This component was also sensitive to the interaction of Emotion and Motion [ $F(2,339) = 11.024, p < 0.001$ ]. Post hoc comparisons revealed three significant pairwise contrasts: i) within static conditions, sNeg evoked greater amplitudes than sPos and sNeu (both  $ps < 0.003$ ), and there were no differences between sNeu and sPos conditions (sNeg > sPos/sNeu pattern) ( $p = 0.905$ ), ii) within dynamic conditions, dNeg and dPos trials evoked greater amplitudes than dNeu (dNeg/dPos > dNeu) (both  $p < 0.01$ ), and no differences were found between dNeg and dPos ( $p = 0.635$ ) and, iii) within emotional conditions, dPos evoked greater amplitudes than sPos ( $p = 0.008$ ), and sNeu evoked greater amplitude than dNeu ( $p < 0.001$ ). The comparison between dNeg and sNeg did not reach significance ( $p = 0.825$ ).

\*\*\* Figure 3 about here \*\*\*

### 3.2. Experimental effects on behavior

Results on number of errors revealed a significant main effect of Emotion [Friedman's test:  $\chi^2(2) = 40.601, p < 0.001$ ]. Post-hoc pairwise tests indicated that Neg condition caused lower number of errors than Pos and Neu [ $Z = -5.652, p < 0.001, r = 0.474$  and  $Z = -5.412, p < 0.001, r = 0.454$ ]. Non-

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significant differences were found between Pos and Neu [ $Z = -0.604, p = 0.546, r = 0.051$ ]. We did not find a main effect of Motion [ $\chi^2(1) = 0.158, p = 0.691$ ]. The interaction between Emotion and Motion also reached significance. Post hoc comparisons showed that Neg stimuli elicited lower number of errors than Pos and Neu in both dynamic [dPos > dNeg:  $Z = -5.697, p < 0.001, r = 0.478$ ; dNeu > dNeg:  $Z = -5.369, p < 0.001, r = 0.450$ ], and static conditions [sPos > sNeg:  $Z = -5.069, p < 0.001, r = 0.425$ ; sNeu > sNeg:  $Z = -5.254, p < 0.001, r = 0.441$ ]. Results involving Neu and Pos comparisons were non-significant [dNeu and dPos:  $p = 0.480$ ; sNeu and sPos:  $p = 0.965$ ] (see Figure 4c).

Reaction times also yielded a significant main effect of Emotion [Friedman's test:  $\chi^2(2) = 17.702, p < 0.001$ ], with Neg [ $Z = -3.011, p = 0.003, r = 0.253$ ] and Neu [ $Z = -4.062, p < 0.001, r = 0.341$ ] eliciting shorter reaction times than Pos, as revealed by post-hoc Wilcoxon signed rank test. No differences between Neg and Neu conditions were found [ $Z = -0.469, p = 0.639, r = 0.039$ ]. As with number of errors, no main effect of Motion was found [ $\chi^2(1) = 0.453, p = 0.501$ ]. Regarding differences among individual conditions, and within emotional conditions, post-hoc pairwise tests showed statistically shorter reaction times in response to dNeg compared to sNeg [ $Z = -3.822, p < 0.001, r = 0.320$ ]; no differences were found in the remaining emotional contrasts (all  $ps > 0.087$ ) (Figure 4a). In dynamic conditions, we observed faster reaction times in response to dNeg compared to dPos and dNeu [ $Z = -4.781, p < 0.001, r = 0.401$ , and  $Z = -2.319, p = 0.020, r = 0.195$ , respectively], and also between dPos and dNeu [ $Z = -2.960, p = 0.003, r = 0.25$ ], showing a dPos > dNeu > dNeg pattern (Figure 4b). Within static conditions, sNeu condition elicited faster reaction times compared to sPos and sNeg [ $Z = -3.817, p < 0.001, r = 0.320$  and  $Z = -3.106, p = 0.002, r = 0.143$ , respectively] and no differences were found between sPos and sNeg ( $p = 0.891$ ).

\*\*\* Figure 4 about here \*\*\*

### 3.3. Relationship between ERPs, behavior, and emotional assessment

In order to analyze the relationship between ERPs, behavior, and emotional assessment, three robust regression analyses were carried out, as indicated. The former, between ERP amplitudes and behavior, showed that reaction times were associated with P1p [ $t(423) = 4.109, p < 0.001$ ] and LPP amplitudes [ $t(423) = -7.550, p < 0.001$ ]. Concretely, a significant and positive relationship was found between

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P1p amplitude and reaction times, while an inverse relationship was found between LPP amplitude and reaction times. Results concerning errors were non-significant in any component ( $p > 0.08$  in all cases).

Additional regressions between ERP amplitudes and the emotional assessment of pictures provided by participants themselves found a significant relationship between P2p and LPP with Valence (negative to positive) and Arousal (calming to arousing) ratings. Thus, P2p amplitude showed a positive regression with Arousal [ $t(423) = 2.43, p = 0.016$ ] and Valence [ $t(423) = 2.76, p = 0.006$ ], and LPP showed it only with Arousal [ $t(423) = 3.70; p < 0.001$ ]. Results involving LPP and Valence were non-significant ( $p > 0.85$ ). Finally, robust regression results concerning emotional assessment and behavioral data revealed inverse regressions between Arousal and both reaction times [ $t(423) = -2.49, p = 0.013$ ] and errors [ $t(423) = -3.07, p = 0.002$ ]. Results involving Valence and behavior were non-significant ( $p > 0.083$  in both cases).

#### 4. Discussion

Our main objective was to explore the joint effect of motion (looming or static 3D-recreated) and emotion on endogenous attention. At the behavioral level, we hypothesized that dynamic threatening stimuli would improve the performance on the stimulus categorization task –an index of endogenous attention- by causing faster reaction times and/or lower number of errors. At the neural level, early (P1 and P2) and late (LPP) ERP components were expected to show increased amplitudes for the dynamic threatening condition. Concerning behavioral data, threatening stimuli improved accuracy in the categorization task by causing lower number of errors, regardless of motion. We also observed faster reaction times to threatening stimuli, but only if they were dynamic. Behavioral data (error and reaction times) confirm our hypothesis and point to an enhanced endogenous attention towards threatening stimuli, both static and dynamic. Previous studies report longer reaction times in response to emotional stimuli (including negative) during indirect tasks, like the one employed here, instead of shorter (De Cesarei & Codispoti, 2006; Lavie, 2005; Lichtenstein-Vidne et al., 2012; Pessoa, 2009). This issue needs, therefore, further exploration, but the experimental design (very heterogeneous across studies) seems to be crucial to explain reaction time discrepancies. For example, we found even shorter reaction times in dynamic threatening stimuli (as compared to static threatening) whereas, in

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all these studies, stimuli were always static. Therefore, our data suggest that looming motion adds additional salience to threatening content providing it an additional urgency to react, in line with the behavioral-urgency hypothesis (Franconeri & Simons, 2003).

Regarding neural responses, early and late attention-related ERP components showed some common patterns for static and dynamic stimuli. Thus, main effects of emotion pointed to an initial bias of attention towards positive stimuli (P1p), both static and dynamic, and a final (LPP) bias to negative. However, interaction effects, which began to be significant in intermediate stages (P2p), revealed some static vs. dynamic differences. Thus, as discussed in detail next, the inclusion of negative stimuli in the attentional focus is produced earlier when they are dynamic.

The main effects, with no interaction, of Motion and Emotion in P1p suggest that, in this initial phase, both variables are processed separately. As discussed below, the integration of both factors is produced some 90 ms later. This lack of interaction suggests that both positive and dynamic conditions are equally efficient in terms of initial attentional selection load and points to the existence of a rapid neural mechanism sensitive to both factors explored here. On one hand, previous data on this component in response to emotional stimuli also report larger amplitudes for emotional –both positive and negative- than for neutral (Alorda et al., 2007; Keil et al., 2001; Kuniecki, Pilarczyk, & Wichary, 2015; Pourtois et al., 2013; Smith et al., 2003) and specifically for negative stimuli (Batty & Taylor, 2003; Rotshtein et al., 2010; Smith et al., 2003). However, our results point out to positive stimuli, also indicating a rapid differential attention allocation as a function of valence, in benefit of the positive content (Alorda et al., 2007; Smith et al., 2003; Vagnoni et al., 2015). This result might be explained by a *positivity offset*, a bias towards pleasant stimuli in a context of low-level arousal (Cacioppo & Gardner, 1999). On the other hand, previous literature describes that P1p arises from the extrastriate visual cortex (Clark, Fan, & Hillyard, 1994; Di Russo et al., 2005; Martínez, Di Russo, Anllo-Vento, & Hillyard, 2001) and concludes that it is sensitive to variations in stimulus physical parameters such as luminance, color, or, importantly to our scope, motion (Meeren, Van Heijnsbergen, & De Gelder, 2005). In sum, even if the interaction effect does not occur at this stage, we observed a

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bias towards looming motion and positive stimuli, as P1p would reflect enhanced attention to both factors independently.

The earliest emotion-motion *interaction* arose at 240 ms with the P2p component, which showed an interesting pattern. Within the dynamic domain, P2p amplitude was significantly greater for both negative and positive stimuli than to neutral, while in the static domain, non-threatening (positive and neutral) stimuli elicited greater amplitudes than threatening. Regarding dynamic effects, previous literature on motion research show enhanced P2 amplitudes at centro-parietal areas (i.e., P2p) in response to expansion motion (simulating approach) as compared to contraction (simulating receding), suggesting that endogenous attention is more intensely directed toward looming motion (Delon-Martin et al., 2006; Kremláček, Kuba, Kubová, & Chlubnová, 2004; Langrová et al., 2006). With respect to the static stimulation, previous research on still images identifies the P2p component as a robust index of affective processing, both for negative (Carretié et al., 2001b; Delplanque et al., 2004; Olofsson & Polich, 2007) and positive content (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). It seems that, among static conditions, there was a clear valence-based gradation (pos > neu > neg) that may be explained in terms of low-level arousal context (Cacioppo & Gardner, 1999), while within the dynamic conditions, the arousal determined the results (emo>neu). Globally, P2p results suggest that the incorporation of the threatening content into the attentional focus seems to be faster in the dynamic than in the static conditions, at least in low arousal situations.

Finally, LPP (450 ms) was sensitive to the main effects of emotion, showing maximal amplitudes towards negative stimuli, and of motion, presenting enhanced amplitudes to dynamic conditions. An interaction was also observed indicating, within dynamic conditions, that both negative and positive stimuli keep their preferential access to attention as we saw in the previous stage (P2p), since both elicit greater LPP amplitudes than neutral. Regarding static conditions, a “pure” negativity bias is observed, since LPP amplitude is greater to negative stimuli than to both positive, which seems to move out of the attentional focus at this stage, and neutral. In relation to this, emotional stimuli, both negative and positive, may further engage top-down resources due to looming motion, since stimuli were closer to participants at the LPP (and its underlying processes) latency than at the P1p

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and P2p latencies. As regards static stimuli, LPP's greater amplitudes to negative than to positive and neutral stimuli suggests more efficiency of negative than positive stimuli in preserving their privileged access to attentional resources even in the absence of motion. LPP, probably the most studied endogenous attention-related ERP component, has been reported to increase toward emotional events, both positive and negative (Cuthbert et al., 2000; Feng et al., 2014; Ito, Larsen, Smith, & Cacioppo, 1998; Keil et al., 2002; Nordström & Wiens, 2012; Olofsson & Polich, 2007; Rigoulot et al., 2011; Schupp et al., 2000; Vagnoni et al., 2015). This sensitivity to emotional stimuli is usually interpreted as an effect of inherent arousal and motivational relevance of stimuli (Olofsson et al., 2008). In any case, enhanced LPP amplitudes in response to static negative as compared to static positive (and neutral) visual stimuli is a relatively frequent finding (Foti et al., 2009; Huang & Luo, 2007; Ito et al., 1998; Keil et al., 2002; Schupp et al., 2000), suggesting a negativity bias in attention in certain circumstances. Again, the experimental design, very heterogeneous in all these studies, seems a crucial factor that may explain whether negative, positive, or both, preferentially engage processes underlying LPP.

Neural activity and both the emotional ratings of (static) stimuli and behavioral performance showed relevant relationships. The P1p component showed significant association with behavior, but not with emotional ratings, showing amplitude enhancement as reaction times in the stimulus categorization task increased. Complementarily, the P2p component presented a significant relationship with emotional ratings -both valence and arousal scores- (positive association between amplitudes of P2p and arousal and valence), but not with behavior. And finally, the LPP component manifested a sort of addition of previous relationships, showing a significant association with both behavior (negative association between LPP and reaction times) and emotional ratings (positive association between LPP and arousal). Therefore, behavioral responses, which constitute a single output resulting from a cascade of different neural processes, were mainly mediated by the initial (P1p) and late (LPP) phases of endogenous attention, while the intermediate (P2p) and late (LPP) phases were more involved in the emotional assessment of the stimulus. Interestingly, the LPP component would combine both emotional outputs (evaluative and behavioral).

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Globally, our results reveal a relevant interaction of motion and emotion interaction worth being further explored due to the relatively frequent presence of dynamic affective stimuli in our real life. As just discussed, neural electrophysiological data show a breakdown of endogenous attention in different phases that evolve in different domains: i) from positive to negative in the emotional domain, more rapidly in the case of dynamic stimuli, ii) from dynamic to broad (static and dynamic), in the motion domain, and from independent to interactive regarding both motion and emotion. To our knowledge, this is the first ERP study analyzing endogenous attention for looming positive, neutral, and negative stimuli employing 3D stimulation. In our opinion, this approach provides at least three relevant advantages to this research area. First, 3D motion adds more realistic experience and increased ecological validity with respect to traditional bidimensional stimulation. Second, and relatedly, it increases attention engagement at least in some stages of processing, according to our data. And third, including positive stimuli besides negative and neutral enables a richer interplay between motion and emotion and provides crucial information on the mechanisms underlying their interaction. The exploration of this interaction of motion and emotion would benefit from overcoming some potential limitations of the present study. Thus, extending the subjective emotional assessment to dynamic emotional stimuli –and not only to static–, controlling the heterogeneity of the trajectory of the stimuli –all the stimuli had the same starting and ending point, but their looming motion differed–, or employing different exemplars of each species in order to reduce habituation processes, are issues to consider in future research.

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**Data availability statement/ Transparency and data sharing:** Data reduction preserving most part of the variance resulted necessarily to further analyze our Emotion (three levels: Pos, Neg, and Neu) x Motion Manipulation (two levels: Static or Dynamic), taking also into account that recordings consisted of a 59 EEG channels (+ vertical and horizontal EOG) x 505 digitized voltages or “time points” x 6 conditions matrix (this matrix is openly available at <https://osf.io/8kdmu/>).

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**Table 1.** Means and standard deviation (in parenthesis) of Valence and Arousal to each stimulus and each experimental condition evaluated by an independent sample of ninety-four participants in order to select stimuli. Both dimensions range from 1 (very negative/very relaxing) to 5 (very positive/very arousing).

	Negative				Positive			Neutral	
	Spider	Snake	Wasp	Butterfly	Frog	Ladybird	Ant	Bird	Fish
<b>Valence (n=94)</b>	1.31 (0.64)	1.70 (0.90)	2.14 (0.99)	2.37 (0.97)	3.53 (0.93)	3.52 (1.08)	1.62 (0.85)	3.01 (0.95)	1.82 (0.83)
		1.72 (0.56)			3.14 (0.72)			2.15 (0.59)	
<b>Arousal (n=94)</b>	4.49 (0.83)	4.29 (0.78)	3.92 (0.87)	3.34 (0.97)	9.21 (0.92)	2.64 (1.05)	3.97 (0.94)	4.41 (0.78)	3.82 (1.07)
		4.22 (0.63)			3.07 (0.68)			3.37 (0.62)	

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**Table 2.** Means and standard deviation (in parenthesis) of luminosity, Valence, and Arousal to each stimulus and experimental condition evaluated by our own sample of seventy-one participants after completing the task. Both dimensions range from 1 (very negative/very relaxing) to 5 (very positive/very arousing).

	Negative		Positive		Neutral	
	Spider	Snake	Ladybird	Frog	Bird	Butterfly
Luminosity	4.69 (16)	1.32 (8.06)	1.8 (12)	3.61 (19.2)	1.2 (7.85)	2.36 (7.12)
	3.00 (12.03)		2.70 (15.6)		1.78 (7.48)	
Valence (n=71)	1.53 (0.94)	2.13 (1.10)	3.69 (0.89)	3.52 (0.82)	3.01 (0.96)	2.80 (1.07)
	1.83 (0.81)		3.60 (0.67)		2.91 (0.81)	
Arousal (n=71)	3.87 (1.40)	4.10 (0.96)	2.76 (1.02)	3.06 (1.01)	3.05 (0.89)	3.07 (0.96)
	3.98 (0.93)		2.91 (0.79)		3.06 (0.64)	

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**Table 3.** Means and standard deviations (in parenthesis) of (i) average number of trials accepted, (ii) number of errors, and (iii) reaction times (expressed in milliseconds).

	dNeg	sNeg	dPos	sPos	dNeu	sNeu
<b>Trials</b>						
Average number of trials	55.68 (6.07)	54.37 (6.07)	54.82 (7.20)	55.06 (6.26)	55.21 (6.11)	54.69 (6.46)
<b>Behavior</b>						
Number of errors	2.01 (2.23)	2.22 (2.24)	4.83 (5.67)	4.69 (5.71)	4.18 (4.13)	4.31 (4.37)
Reaction times (ms)	709 (8.61)	728 (10.12)	729 (9.20)	726 (9.41)	721 (9.72)	715 (8.89)

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**Table 4.** Means and standard deviations (in parenthesis) of P1p, P2p, and LPP spatial factor scores (linearly related with amplitudes) to each experimental condition, and results of the two-way ANCOVA involving Emotion and Motion factors (F, degrees of freedom [*df*], and probability [*p*]). Significant results are shown in bold.

ANCOVAs															
	Means (SD)						Emotion			Motion			Emotion x Motion		
	dNeg	sNeg	dPos	sPos	dNeu	sNeu	F	df	p	F	df	p	F	df	p
<i>TF5</i>															
TF5SF1	0.053 (0.129)	-0.163 (0.125)	0.160 (0.103)	-0.065 (0.122)	0.004 (0.118)	0.012 (0.113)	0.689	2, 341	0.503	2.780	1, 352	0.096	0.944	2, 341	0.390
TF5SF2	0.120 (0.118)	0.002 (0.117)	0.322 (0.098)	-0.193 (0.098)	-0.077 (0.114)	-0.174 (0.123)	<b>3.152</b>	<b>2, 341</b>	<b>0.044</b>	<b>15.464</b>	<b>1, 351</b>	<b>0.000</b>	<b>2.497</b>	<b>2, 341</b>	<b>0.084</b>
<i>TF4</i>															
TF4SF1	0.076 (0.119)	-0.034 (0.114)	0.041 (0.116)	-0.018 (0.130)	-0.193 (0.102)	0.128 (0.128)	0.254	2, 339	0.77	3.524	1, 346	0.061	7.246	2, 339	0.001
TF4SF2	-0.200 (0.113)	0.000 (0.116)	-0.115 (0.100)	0.502 (0.128)	-0.422 (0.105)	0.234 (0.119)	<b>13.372</b>	<b>2, 340</b>	<b>0.000</b>	<b>88.131</b>	<b>1, 347</b>	<b>0.000</b>	<b>7.734</b>	<b>2, 339</b>	<b>0.001</b>
<i>TF1</i>															
TF1SF1	0.225 (0.119)	0.209 (0.115)	0.065 (0.120)	-0.080 (0.120)	-0.392 (0.107)	-0.026 (0.117)	<b>23.882</b>	<b>2, 342</b>	<b>0.000</b>	<b>3.594</b>	<b>1, 340</b>	<b>0.059</b>	<b>11.024</b>	<b>2, 339</b>	<b>0.000</b>
TF1SF2	0.324 (0.119)	0.305 (0.112)	-0.043 (0.117)	-0.075 (0.117)	-0.475 (0.107)	-0.035 (0.118)	28.412	2, 341	0.000	8.343	1, 340	0.004	7.256	2, 336	0.001

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### Figure captions

**Figure 1.** Schematic illustration of the task.

**Figure 2.** tPCA factor loadings after promax rotation. Lines depict temporal loadings and topographies represent spatial loadings. Temporal factors showing significant results are highlighted in color.

**Figure 3.** Grand averages representing channels showing maximum loading in each SF: two occipital (O1 and O2) and two parieto-occipital (PO3 and PO4) electrodes for each component (P1p, P2p, and LPP) in response to static and dynamic stimuli (dNeg, sNeg, dPos, sPos, dNeu, sNeu).

**Figure 4.** Bar graphs representing means and standard error of means (error bars) of behavioral data. Figures (a) and (b) represent reaction times, whereas (c) represent number of errors for each condition. Note that number of errors bar graph is grouped by motion as no differences were found within each emotion, not as occurs in reaction times. Significance corresponds to post-hoc Bonferroni contrasts (\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ ).

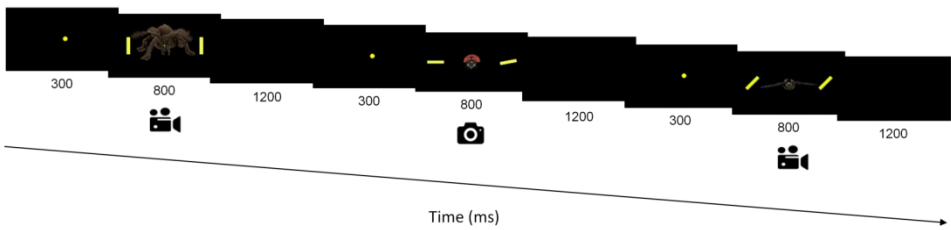


Figure 1. Schematic illustration of the task.



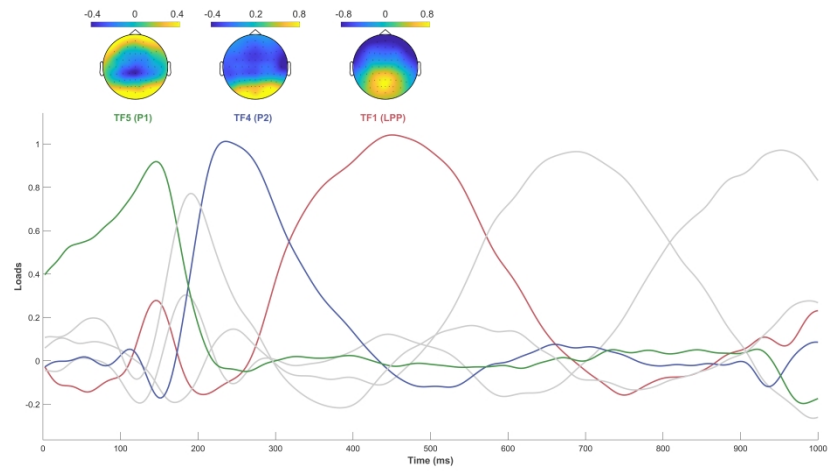


Figure 2. tPCA factor loadings after promax rotation. Lines depict temporal loadings and topographies represent spatial loadings. Temporal factors showing significant results are highlighted in color.

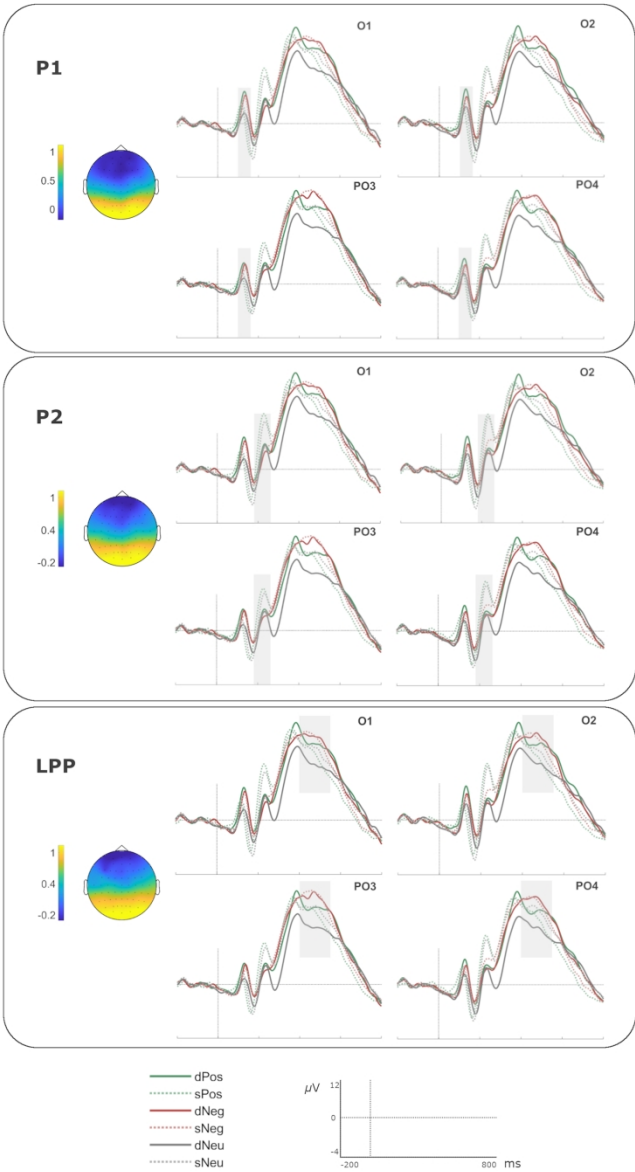


Figure 3. Grand averages representing channels showing maximum loading in each SF: two occipital (O1 and O2) and two parieto-occipital (PO3 and PO4) electrodes for each component (P1p, P2p, and LPP) in response to static and dynamic stimuli (dNeg, sNeg, dPos, sPos, dNeu, sNeu).

197x349mm (300 x 300 DPI)

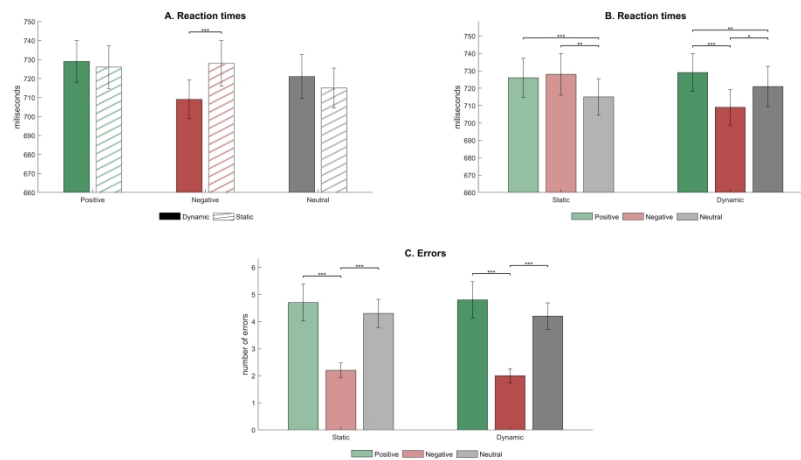


Figure 4. Bar graphs representing means and standard error of means (error bars) of behavioral data. Figures (a) and (b) represent reaction times, whereas (c) represent number of errors for each condition. Note that number of errors bar graph is grouped by motion as no differences were found within each emotion, not as occurs in reaction times. Significance corresponds to post-hoc Bonferroni contrasts (\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ ).

374x187mm (300 x 300 DPI)