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Is the sunny side up and the dark side down? Effects of stimulus type and valence on a spatial detection task

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ABSTRACT
In verbal communication, affective information is commonly conveyed to others through spatial terms (e.g. in "I am feeling down", negative affect is associated with a lower spatial location). This study used a target location discrimination task with neutral, positive and negative stimuli (words, facial expressions, and vocalizations) to test the automaticity of the emotion-space association, both in the vertical and horizontal spatial axes. The effects of stimulus type on emotion-space representations were also probed. A congruency effect (reflected in reaction times) was observed in the vertical axis: detection of upper targets preceded by positive stimuli was faster. This effect occurred for all stimulus types, indicating that the emotion-space association is not dependent on sensory modality and on the verbal content of affective stimuli.

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Emotion; space; words; faces; vocalizations; reaction times

Across different languages, spatial terms are commonly used to communicate emotions. In expressions such as "I am feeling down" (i.e. "Sinto-me em baixo") or "being in high spirits" (i.e. "com a moral em alta"), an affective state (e.g. sadness/happiness) is conveyed without using an affective term. These examples demonstrate the intricate links between emotion and space representations and reflect an association between emotion and space that may be modulated by language. The conceptual metaphor theory (Lakoff, 2014; Lakoff & Johnson, 1980) argues that bodily experiences (e.g. ones' posture when experiencing sadness) are integrated in conceptual mappings that link concrete (e.g. space) and abstract (e.g. emotion) concepts, such as "positive is up/right" vs. "negative is down/left". The body specificity hypothesis (Casasanto, 2009) posits that valence is horizontally mapped according to handedness: positive concepts are spatially associated with the dominant hand side, whereas negative concepts are associated with the non-dominant hand side. Based on this account, mappings involving vertical spatial terms are applied to both right- and left-handers, whereas mappings using horizontal spatial terms (e.g. "positive is right") are only applied to right-handers (Figure 1).

There is a robust body of evidence showing that emotion-space mappings are reflected in a congruency effect that influences behaviour (Damjanovic & Santiago, 2016; de la Vega, de Filippis, Lachmair, Dudschig, & Kaup, 2012; Gozli, Chow, Chasteen, & Pratt, 2013; Kong, 2013; Meier & Robinson, 2004; Montoro, Contreras, Elosúa, & Marmolejo-Ramos, 2015; Xie, Huang, Wang, & Liu, 2015). Spatial targets presented after, or concomitantly with, affective words are detected faster in congruent affective/spatial conditions (i.e. positive/upper and negative/lower) (Meier & Robinson, 2004; Xie et al., 2015). Even though an emotion-space association has been consistently replicated for the positive/upper condition, this effect is less consistent in the negative/lower condition (Damjanovic & Santiago, 2016; Gozli et al., 2013; Lakens, 2012; Lynott & Coventry, 2014; Meier & Robinson, 2004; Montoro et al., 2015; Xie et al., 2015).

Compared to the vertical axis, an association between emotion and horizontal space (reflected in reaction times) is only observed under specific task

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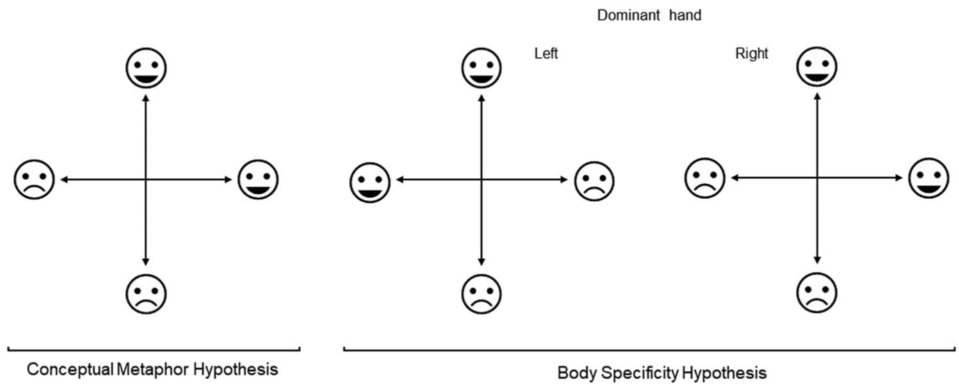

Figure 1. Schematic illustration of the emotion-space association according to the conceptual metaphor theory and the body specificity hypothesis.

conditions, such as: employing a response mapping that explicitly associates valence and body side – left *vs*. right hand (de la Vega et al., 2012); using a congruent hand-response side assignment (i.e. left/right dominant hand side – de la Vega, Dudschig, De Filippis, Lachmair, & Kaup, 2013; Gozli et al., 2013) instead of instructing participants to discriminate left from right side (Xie et al., 2015); providing instructions for explicit categorisation of the stimulus preceding a target (de la Vega et al., 2013; Kong, 2013) instead of a more shallow or implicit processing (Gozli et al., 2013). This pattern of results mirrors the evidence found when probing another spatial association, the SPARC/SMARC effect (Rusconi, Kwan, Giordano, Umiltà, & Butterworth, 2005, 2006), in which high (compared to low) pitch facilitates the discrimination of upper/right (*vs*. lower/left) locations. Together, the existing findings suggest that the emotion-space associations do not emerge automatically in the horizontal axis. The null effects may result not only from methodological differences, but they may also be modulated by language (Goodhew, McGaw, & Kidd, 2014; Lidji, Kolinsky, Lochy, & Morais, 2007; Rusconi, Kwan, Giordano, Umiltà, & Butterworth, 2006). For example, Lidji et al. (2007) posit that the SPARC effect is more salient in the vertical axis because terms such as "high" and "low" are more commonly associated with vertical terms in our everyday lives. Indeed, whereas expressions such as "I am feeling down" are common in our everyday lives, the same is not true for "I am feeling left". Hence, if specific affective concepts (e.g. *happiness*) systematically co-occur with vertical ("up"), but not horizontal ("right") spatial terms, the presentation of positive stimuli might more easily trigger the spatial concept "up" instead of "right" (Goodhew et al., 2014). Therefore, the specificities of a given language may account for the null effects observed in the horizontal axis when testing the emotion-space association (Gozli et al., 2013; Xie et al., 2015).

It is also worth noting that the emotion-space association (more commonly reported in the vertical axis) is also more consistently reflected in reaction times compared to behavioural measures of accuracy. The observation that reaction times are more sensitive to this type of association may be explained by differences in the neurofunctional mechanisms underpinning reaction times and accuracy, and in how these mechanisms are modulated by the interval between cue offset (i.e. affective stimulus) and target onset (van Ede, de Lange, & Maris, 2012). There is evidence that reaction time effects may occur in the absence of accuracy improvement (van Ede et al., 2012), and vice-versa (Kopf, Dresler, Reicherts, Herrmann, & Reif, 2013; Marx et al., 2011), and that the two types of effects have a different time course (van Ede et al., 2012). This suggests that there is not a single underlying process that accounts for behavioural measures, i.e. accuracy and reaction times. Specifically, improvements in reaction times and accuracy were found to be accompanied with anticipatory sensory suppression of neural oscillations (in the alpha and beta frequency bands) of the electroencephalogram (EEG) when the cue-target interval was long (van Ede et al., 2012). However, with a short cue-target interval, improvements were observed in reaction times only, in the absence of anticipatory suppression of neural oscillations (van Ede et al., 2012). This pattern of findings suggested that whereas reaction time effects were subserved by both preparatory and non-preparatory cognitive processes, accuracy effects relied on preparatory processes only. When the task involves short cue-target intervals, participants are not able to retrieve information from the cue before target presentation, which prevents preparatory processes and consequently no improvement in accuracy rates is observed. Nonetheless, non-preparatory (post-target) processes may still occur, explaining the reaction time improvement effect observed in the literature (van Ede et al., 2012; Xie et al., 2015). Another explanation is that in paradigms such as the one used by Xie et al. (2015), in which an affective stimulus (cue) is presented before a spatial target, accuracy effects are dependent on the information conveyed by the cue (Bonato, Lisi, Pegoraro, & Pourtois, 2016; Kerzel, Zarian, & Souto, 2009; Prinzmetal, McCool, & Park, 2005). Specifically, when the cue conveys information regarding the possible location of the target, both reaction times and accuracy rates are affected. However, when the cue does not convey information indicating the possible location of the target, only reaction times are affected (Bonato et al., 2016; Kerzel et al., 2009; Prinzmetal et al., 2005). This idea is consistent with the null effects reported by studies using spatial cueing tasks, in which the cues (e.g. affective stimuli and time-related concepts) were not informative regarding target location (Marmolejo-Ramos, Montoro, Elosúa, Contreras, & Jiménez-Jiménez, 2014; Montoro et al., 2015; Ouellet, Santiago, Funes, & Lupiáñez, 2010; Xie et al., 2015).

The existing studies probing the emotion-space association are restricted to the visual modality and have used either words (de la Vega et al., 2012, 2013; Xie et al., 2015) or facial expressions (Damjanovic & Santiago, 2016; Kong, 2013). However, emotional meaning is not only communicated visually. To our knowledge, the only exception is a study that tested the emotion-space association using spoken words with neutral prosody (Montoro et al., 2015): a congruency effect was observed when attention was directed to the words' valence but not to their phonemic properties. While Montoro et al. (2015) presented stimuli in the auditory modality, they still relied on semantic information to convey affective meaning. However, in our daily lives, we also decode emotions from sounds that do not contain linguistic information, such as nonverbal vocalizations (e.g. laughs; cries; screams; Belin, Fecteau, & Bédard, 2004). Affective vocalizations elicit enhanced attentional resources and are associated with increased recognition accuracy when compared with neutral vocalizations (Hawk, van Kleef, Fischer, & van der Schalk, 2009; Liu et al., 2012; Pell et al., 2015; Pinheiro, Barros, & Pedrosa, 2016). Moreover, previous studies showed that affective vocalizations modulate performance in bisection tasks (i.e. a shift of the bisection bias to the right by positive stimuli), even when attention is not focused on stimulus valence (Cattaneo et al., 2014).

1.1. The current study and hypotheses

As mentioned before, a robust body of evidence has demonstrated that the emotion-space associations affect behavioural responses (de la Vega et al., 2012; Gozli et al., 2013; Kong, 2013; Meier & Robinson, 2004; Montoro et al., 2015; Xie et al., 2015). However, since most of the studies used visual affective stimuli containing linguistic information (de la Vega et al., 2012; de la Vega et al., 2013; Kong, 2013; Meier & Robinson, 2004; Xie et al., 2015), it is not clear whether these associations are generalisable to non-linguistic stimuli (e.g. faces) (Damjanovic & Santiago, 2016; Kong, 2013) or stimuli that belong to other sensory modalities (e.g. vocalizations).

The current study probed how stimulus type (words, faces, vocalizations) and valence (neutral, positive, negative) affect spatial detection, examining the association between emotion and space in both horizontal and vertical axes. The experimental task used by Xie et al. (2015) was adapted to include words, facial expressions and non-linguistic vocalizations differing in valence, which preceded a target (dot) whose location the participants had to discriminate. As in previous studies (Meier & Robinson, 2004; Montoro et al., 2015; Xie et al., 2015), accuracy and reaction time measures were examined. As the emotion-space association seems to be more automatic in the vertical axis (Damjanovic & Santiago, 2016; Gozli et al., 2013; Marmolejo-Ramos, Elosúa, Yamada, Hamm, & Noguchi, 2013; Xie et al., 2015), we hypothesised that the detection of upper/lower targets would be facilitated following a positive/negative stimulus respectively, even if participants were not explicitly instructed to attend to stimulus valence. We expected this effect to be reflected in reaction times, but not in accuracy rates (Gozli et al., 2013; Meier & Robinson, 2004; Xie et al., 2015), and to be more pronounced in the positive/upper condition (Gozli et al., 2013; Lynott & Coventry, 2014; Montoro et al., 2015; Xie et al., 2015).

Further, we expected the emotion-space association to be observed irrespective of stimulus type, i.e. facial expressions (Damjanovic & Santiago, 2016; Kong, 2013), words (Gozli et al., 2013; Kong, 2013; Xie et al., 2015), and non-linguistic vocalizations (Cattaneo et al., 2014; Montoro et al., 2015). This would support the notion that the emotion-space association is independent of sensory modality (Cattaneo, Schiavi, et al., 2014; Lakoff, 2014) and of the verbal content of affective stimuli (Damjanovic & Santiago, 2016; Kong, 2013).

2. Method

2.1. Participants

A power analysis was conducted using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) to estimate the sample size necessary to achieve the desired statistical power (effect size [η_p^2] of .06, $p < .05$, and power of .95 following Xie et al., 2015). This analysis indicated that at least 42 participants should be tested per axis. A total of 123 college students (49 males, $M_{age} = 21.4$, $SD = 3.06$ years) participated in the experiment in exchange of credits or with the possibility to win a monetary compensation. To ensure that only participants who payed attention to the experiment were included in the final analysis, participants with an accuracy below 60% either in the spatial or in the memory task were discarded from the analysis ($n = 24$). Further, participants with mean reaction times above 500 ms were also discarded ($n = 3$). Additionally, 8 participants who were left-handed were excluded. Ultimately, 88 participants (38 males, $M_{age} = 21.5$, $SD = 3.28$ years) were considered for further analyses: 44 participants (20 males, $M_{age} = 21.3$, $SD = 3.54$) performed the task in the vertical axis, and 44 participants (18 males, $M_{\text{age}} = 21.6$, $SD = 3.04$ years) performed the task in the horizontal axis.

All reported normal or corrected-to-normal vision and provided written informed consent prior to the experiment. The study was approved by a local Ethics Committee (University of Minho, Braga, Portugal).

2.2. Materials

2.2.1. Spatial target discrimination task

The task included 224 stimuli (facial expressions, words, and nonverbal vocalizations) that were selected as a function of valence ratings (positive, negative, and neutral).

A total of 78 facial expressions (260 × 360 pixels) were chosen from the Karolinska Directed Emotional Faces battery (Goeleven, De Raedt, Leyman, & Verschuere, 2008; Lundqvist, Flykt, & Öhman, 1998). The positive valence set contained faces portraying happiness, whereas the negative valence set contained stimuli portraying either sadness, fear, disgust or anger. A similar number of male and female faces was included in each condition. All stimuli were trimmed and adjusted to the same size (W × H: 260 × 360 pixels) to ensure stimulus consistency and to minimise potential distractions (e.g. actor's hairline). They were presented centrally at a visual angle of 10° 52′ 0.92″.

Words were chosen from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999) set, based on dimensional affective ratings adapted for the European Portuguese (Soares, Comesaña, Pinheiro, Simões, & Frade, 2012), and category norms derived from Stevenson, Mikels, and James (2007). The positive valence set contained words conveying happiness, and the negative valence set contained words conveying either sadness, fear, disgust, or anger. The selected words were controlled for grammatical class (all nouns), number of letters, and number of syllables, resulting in 26 positive (letters: $M = 6.00$, $SD = 0.89$; syllables: $M = 2.65$, $SD = 0.56$), 26 negative (letters: $M = 6.19$, $SD = 0.85$; syllables: $M = 2.58$, $SD = 0.50$), and 26 neutral words (letters: $M = 5.85$, $SD = 0.83$; syllables: $M = 2.46$, $SD = 0.51$). A one-way ANOVA was used to test for differences in the number of letters and syllables between positive, negative, and neutral words. No significant effects were found ($p > .05$).

The set of nonverbal vocalizations was composed of 46 vocal sounds selected from the Montreal Affective Voices battery (MAV; Belin, Fillion-Bilodeau, & Gosselin, 2008; validated by Vasconcelos, Dias, Soares, & Pinheiro, 2017), and 16 vocal sounds selected from a corpus of non-linguistic vocalizations validated for the Portuguese population by Lima, Castro, and Scott (2013). The positive valence set consisted of vocalizations expressing happiness, amusement, and achievement, and the negative valence set consisted of anger, fear, disgust, pain, and sadness vocalizations. The neutral valence set contained 10 vocalizations selected from the MAV battery; some vocalizations were repeated (six vocalizations were presented three times, and the remaining four vocalizations were repeated twice) to reach the same number of stimuli as in the other valence sets. Positive and negative vocalizations did not differ in pitch [$U = 287.50$, $z = .924$, $p > .05$] or duration [$U = 271.00$, $z = -1.22$, $p > .05$].[1]

2.2.2. Memory task

To accurately perform the spatial target discrimination task, participants only had to pay attention to the target location. Nonetheless, to ensure that participants also attended to the affective stimuli that preceded the targets, a memory task was designed. Participants were instructed to pay attention to all the stimuli presented during the spatial discrimination task, as the affective stimuli were the focus of the memory task. Participants were asked to discriminate between familiar (i.e. stimuli presented in the spatial target detection task) and novel stimuli. A total of 15 facial expressions, 15 words, and 10 nonverbal vocalizations were chosen from the set of stimuli used in the spatial target detection task (familiar stimuli). The novel stimuli were chosen from the same batteries used in the spatial target detection task, and consisted of 15 facial expressions, 15 words, and 10 nonverbal vocalizations.

2.3. Procedure

The experiment followed a 3 (stimulus type: facial expressions, words, nonverbal vocalizations) × 3 (stimulus valence: positive, negative, neutral) × 2 (location of spatial target: up *vs*. down; left *vs*. right) within-subjects' design for each spatial axis (horizontal or vertical).

Before the beginning of the experiment, participants were randomly assigned to the horizontal or to the vertical axis. They were informed there were two tasks: a spatial target detection task and a memory task. In the first, they were required to identify the location of a dot and, in the second, their attention and memory were tested. Participants were seated at a distance of 50 cm from the computer screen. Visual stimuli were presented in a white background. First, a black cross was presented at the centre of the screen for 500 ms; then, either a facial expression, a word (72-point size, Baskerville Old Face font), or a nonverbal vocalization was presented. After that, two blank squares (1.3 cm × 1.3 cm), located either vertically or horizontally according to the condition the participant was assigned to, appeared on the screen for 100 ms. Afterwards, a black dot (5 mm) appeared during 30 ms. After the dot disappeared, the squares remained on the screen for 2300 ms or until a response from the participant. Participants responded accordingly to the axis they were assigned to. If the dot appeared in the vertical axis, participants were instructed to press the "Y" key using the right hand when the dot appeared in the upper location, and to press the "V" key using the left hand when the dot appeared in the lower location. If the dot appeared only in the horizontal axis, participants were instructed to press the "M" key using the right hand when the dot appeared on the right, and to press the "Z" key using the left hand when the dot appeared on the left (following Xie et al., 2015, the response keys remained the same across participants).

The next trial started after a blank screen presented for 2500 ms. All cues were presented twice to ensure that each stimulus cued both locations (up/down or right/ left; Figure 2).

In the memory task, a fixation cross was presented for 500 ms, followed by a stimulus (facial expression, word, or nonverbal vocalization) that lasted 1500 ms. After stimulus presentation, the question "Present?" appeared on the screen. Participants were instructed to press the "S" key if they considered that the stimulus was presented in the first experiment, and to press the "N" key if they considered that the stimulus was not presented before. If they took more than 2300 ms to make a response, a blank screen appeared for 1500 ms, and the next trial started.

Both tasks included a short training session to provide the participants the opportunity to get familiarised with the procedure.

2.4. Statistical analysis

To probe the emotion-space association, an omnibus repeated-measures analysis of variance (ANOVA) was run on mean reaction times and response accuracy for both axes: valence (neutral, positive, negative),

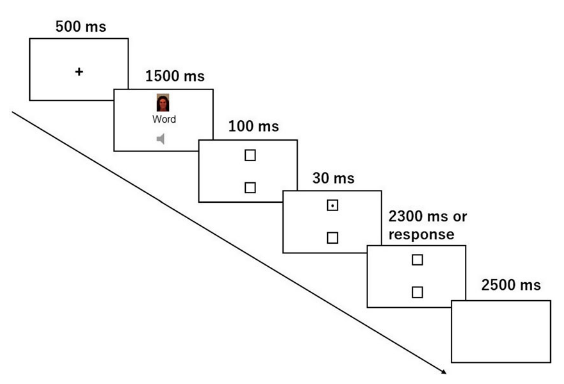

Figure 2. Schematic illustration of an experimental trial.

stimulus type (facial expressions, words, vocalizations), and target location (vertical: lower/upper; horizontal: left/right) were included as within-subject factors, and axis (vertical, horizontal) was included as between-subjects factor. Additionally, based on previous reports of differences in emotion-space associations for the horizontal *vs.* vertical axis (de la Vega et al., 2012; Gozli et al., 2013; Marmolejo-Ramos et al., 2013; Xie et al., 2015), the omnibus ANOVA was followed by separate ANOVAs for each axis, with the same within-subject factors.

When necessary, analyses were corrected for sphericity violations using the Greenhouse-Geisser adjustment. Main effects were followed with pairwise comparisons between conditions, using the Sidak correction for multiple comparisons.

3. Results

3.1. Reaction times

Only correct responses were considered in the analysis of RT.

A main effect of stimulus type, $F(2, 172) = 23.24$, $p < .001$, $\eta_p^2 = .213$, revealed that spatial detection was slower for targets preceded by facial expressions compared to words ($p < .001$) and vocalizations ($p < .001$). Furthermore, a significant valence × target location interaction, $F(2, 172) = 5.14$, $p = .007$, $\eta_p^2 = .056$, was observed. This interaction was followed up by inspecting the effects of valence on each target location condition separately. Whereas no effects were found in the lower/left condition, $F(2, 172) = 2.02$, $p = .136$, $\eta_p^2 = .023$, valence affected differently the processing of targets presented in upper/right locations, $F(2, 172) = 3.71$, $p = .026$, $\eta_p^2 = .041$: positive stimuli elicited faster responses compared to negative stimuli ($p = .021$). Moreover, the interaction was also examined by inspecting the effects of target location for each valence condition separately. A significant effect was observed in the negative condition, $F(1, 86) = 4.60$, $p = .035$, $\eta_p^2 = .051$: participants showed faster responses for targets presented at lower/left locations than targets presented at upper/right locations. No significant effects were observed for the neutral, $F(1, 86) = 2.72$, $p = .103$, $\eta_p^2 = .031$, and for the positive condition, $F(1, 86) = .84$, $p = .362$, $\eta_p^2 = .010$ (Table 1).

3.1.1. Vertical axis

A main effect of stimulus type, $F(2, 86) = 18.04$, $p < .001$, $\eta_p^2 = .296$, was observed: participants were slower at identifying the location of targets preceded by facial expressions than by words ($p < .001$) or vocalizations ($p < .001$). The analysis also revealed a significant valence × target location interaction, $F(2, 86) = 3.85$, $p = .025$, $\eta_p^2 = .082$. This interaction was followed up by inspecting the effects of valence on each target location condition separately. Whereas no effects were found in the lower condition, $F(2, 86) = .338$, $p = .714$, $\eta_p^2 = .008$, valence affected differently the processing of targets presented in upper locations, $F(2, 86) = 4.35$, $p = .016$, $\eta_p^2 = .092$: positive stimuli elicited faster responses compared to negative ($p = .028$) and neutral stimuli ($p = .048$). Additionally, the interaction was also examined by inspecting the effects of target location considering each valence condition separately, but no significant effects were observed either for the neutral, $F(1, 43) = 1.85$, $p = .181$, $\eta_p^2 = .041$, positive, $F(1, 43) = 1.081$, $p = .304$, $\eta_p^2 = .025$, or negative conditions, $F(1, 43) = 2.49$, $p = .122$, $\eta_p^2 = .055$ (Figure 3; Table 2).

3.1.2. Horizontal axis

A main effect of stimulus type, $F(2, 86) = 9.103$, $p < .001$, $\eta_p^2 = .175$, revealed that spatial detection was slower for targets preceded by facial expressions compared to words ($p = .004$) and vocalizations ($p = .003$). Regarding the valence × target location interaction, relevant for the current study, no significant effect was observed $F(2, 86) = 1.70$, $p = .189$, $\eta_p^2 = .038$. Further, the effect size was small (Cohen,

Table 1. Mean reaction times (ms) per condition in both vertical and horizontal axes.

		Positive		Negative		Neutral	
Stimulus type	Target location	*M*	*SE*	*M*	*SE*	*M*	*SE*
Facial expressions	Up/Right	373.39	6.22	378.39	5.71	377.45	6.13
	Down/Left	373.38	7.74	370.40	6.40	369.36	5.67
Words	Up/Right	359.60	5.95	363.43	6.17	362.22	5.95
	Down/Left	363.16	5.72	359.58	5.64	361.71	5.72
Vocalizations	Up/Right	358.63	5.46	369.00	6.28	362.12	6.43
	Down/Left	362.80	5.99	361.27	6.43	355.58	6.17

Note: *M* = Mean; *SE* = Standard Error.

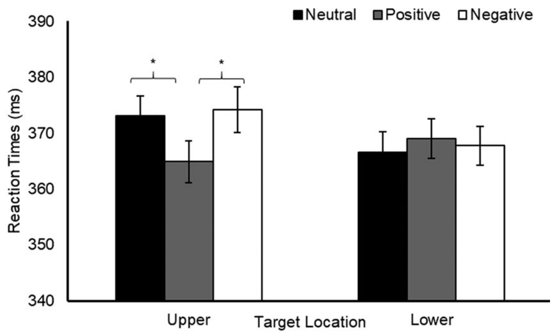

Figure 3. Mean reaction times (milliseconds – ms) in the spatial target detection task as a function of target location in the vertical axis. Standard errors are represented by vertical bars. Significant interactions between valence and target location are represented by *$p < .05$, **$p < .01$, ***$p < .001$.

1988), particularly if considering prior studies in which a significant interaction was reported ($\eta_p^2 = .14$ in Xie et al., 2015). No other significant effects or interactions were found ($p > .05$; Tables 3 and 4).

3.1.3. The effect of neutral trials

An additional analysis was performed to rule out a pre-existing spatial bias in favour of one of the two locations, which could contaminate the valence x target location interaction: neutral trials were subtracted from the affective trials. The statistical analysis followed the same procedure as described above. The effects of the main analyses remained significant. A full description of results is presented in Supplementary File A.

Table 2. Mean reaction times (ms) per condition in the vertical axis.

		Positive		Negative		Neutral	
Stimulus type	Target location	*M*	*SE*	*M*	*SE*	*M*	*SE*
Facial expressions	Up	374.47	6.55	382.66	8.20	383.62	8.88
	Down	376.61	8.33	374.43	8.48	373.35	7.15
Words	Up	361.98	8.01	363.30	8.50	366.34	8.80
	Down	365.01	7.41	358.89	6.87	366.15	7.48
Vocalizations	Up	358.17	7.52	376.71	8.47	369.49	9.86
	Down	365.44	7.69	369.94	8.22	360.24	7.70

Note: *M* = Mean; *SE* = Standard Error.

Table 3. Mean reaction times (ms) per condition in the horizontal axis.

		Positive		Negative		Neutral	
Stimulus type	Target location	*M*	*SE*	*M*	*SE*	*M*	*SE*
Facial expressions	Left	370.15	10.29	366.38	9.59	365.38	8.80
	Right	372.30	9.34	375.13	10.69	371.28	8.78
Words	Left	361.30	9.37	360.28	9.07	357.28	8.66
	Right	357.22	7.67	363.57	8.94	357.71	8.02
Vocalizations	Left	360.16	9.18	352.61	9.90	350.92	9.65
	Right	359.08	7.91	361.29	9.26	354.75	8.26

Note: *M* = Mean; *SE* = Standard Error.

Table 4. Summary of the statistical analysis (*F* and *p* values) of reaction times in the spatial detection of targets presented in the horizontal *vs.* vertical axes.

	Both axes		Horizontal axis		Vertical axis	
	F	*P*	*F*	*p*	*F*	*p*
Stimulus type	23.24	<.001***	9.10	<.001***	18.04	< .001***
Valence	1.02	.36	1.35	.27	1.51	.23
Target location	1.53	.22	.83	.37	.71	.41
Stimulus type × valence	.74	.56	.27	.90	2.16	.08
Stimulus type × target location	1.15	.32	.74	.48	.46	.63
Valence × target location	5.14	.007**	1.70	.19	3.85	.025*
Stimulus type × valence × target location	.19	.943	.031	.99	.40	.81

*$p < .05$, **$p < .01$, ***$p < .001$.

3.2. Accuracy

A main effect of stimulus type, $F(2, 172) = 13.34$, $p < .001$, $\eta_p^2 = .134$, indicated that spatial detection was less accurate after the presentation of vocalizations compared to words ($p < .001$) and facial expressions ($p = .001$). Further, a significant interaction between stimulus type and valence, $F(4, 344) = 4.54$, $p = .001$, $\eta_p^2 = .050$, was observed. We examined this interaction by probing the effects of stimulus type on each valence condition separately. Whereas no significant effect was found when considering neutral stimuli, $F(2,172) = 1.40$, $p = .249$, $\eta_p^2 = 016$, we observed that participants were more accurate when responding to targets after positive faces than after positive vocalizations ($p = .034$) (effect of positive valence – $F(2, 172) = 3.97$, $p = .021$, $\eta_p^2 = .044$), and they were less accurate when responding to targets following negative vocalizations compared to both negative faces and words ($p < .001$) (effect of negative valence – $F(2, 172) = 22.59$, $p < .001$, $\eta_p^2 = .208$). This interaction was also examined by probing the effects of valence per stimulus type: whereas no significant effects were found for faces, $F(2, 172) = 1.88$, $p = .156$, $\eta_p^2 = .021$, or words, $F(2, 172) = 2.51$, $p = .084$, $\eta_p^2 = .028$, the effect of vocalizations reached significance, $F(2, 172) = 5.36$, $p = .007$, $\eta_p^2 = .059$: negative vocalizations elicited less accurate responses than neutral vocalizations ($p < .001$). No interaction between target location and valence was observed, $F(2, 172) = .73$, $p = .484$, $\eta_p^2 = .008$.

3.2.1. Vertical axis

A main effect of stimulus type, $F(2, 86) = 7.41$, $p = .001$, $\eta_p^2 = .147$, revealed that spatial detection was less accurate after the presentation of vocalizations compared to both facial expressions ($p = .021$) and words ($p = .005$). Further, a significant interaction between stimulus type and valence, $F(4, 172) = 4.40$, $p = .002$, $\eta_p^2 = .093$, was observed, indicating that not only stimulus type but also valence affected spatial detection. We examined this interaction by probing the effects of stimulus type on each valence condition separately. Specifically, there was no effect for neutral valence, $F(2, 86) = .27$, $p = .768$, $\eta_p^2 = .006$. While a significant effect was observed for positive valence, $F(2, 86) = 3.56$, $p = .040$, $\eta_p^2 = .076$, pairwise comparisons did not reveal any differences as a function of stimulus type. A significant effect was observed for negative vocalizations, $F(2, 86) = 14.55$, $p < .001$, $\eta_p^2 = .253$, which played a disruptive effect on performance in the spatial detection task (i.e. elicited fewer correct responses) relative to words ($p < .001$) and facial expressions ($p = .008$). We also examined valence effects for each stimulus type separately. This analysis yielded a significant effect of valence in the case of vocalizations, $F(2, 86) = 5.29$, $p = .013$, $\eta_p^2 = .110$, showing that performance was more affected (i.e. fewer correct responses) by negative compared to neutral vocalizations ($p < .001$). No significant effects were found either for faces, $F(2, 86) = 1.14$, $p = .326$, $\eta_p^2 = .026$, or words, $F(2, 86) = 2.72$, $p = .081$, $\eta_p^2 = .059$. Specifically, no interaction between valence and target location was found, $F(2, 86) = 1.65$, $p = .198$, $\eta_p^2 = .037$ (Table 5).

3.2.2. Horizontal axis

A main effect of stimulus type, $F(2, 86) = 7.11$, $p = .003$, $\eta_p^2 = .142$, indicated that spatial detection was less accurate after the presentation of vocalizations compared to words ($p = .008$) and facial expressions ($p = .035$). No interaction between target location and valence was observed, $F(2, 86) = .005$, $p = .995$, $\eta_p^2 = .000$ (Table 6).

4. Discussion

This study demonstrated that the links between emotion and space are independent of sensory modality and of the verbal content of affective stimuli. Further, the current results show that these links are enhanced in the vertical axis.

Table 5. Accuracy rates (%) per condition in the vertical axis.

		Positive		Negative		Neutral	
Stimulus type	Target location	*M*	*SE*	*M*	*SE*	*M*	*SE*
Facial expressions	Left	97.55	0.57	96.85	0.75	97.47	0.60
	Right	98.16	0.54	97.64	0.54	98.08	0.41
Words	Left	97.20	0.55	97.66	0.49	97.99	0.39
	Right	97.47	0.66	98.92	0.38	97.55	0.45
Vocalizations	Left	96.25	0.85	95.63	0.63	97.90	0.52
	Right	96.33	0.93	95.54	0.64	97.03	0.67

Note: *M* = Mean; *SE* = Standard Error.

Table 6. Accuracy rates (%) per condition in the horizontal axis.

		Positive		Negative		Neutral	
Stimulus type	Target location	*M*	*SE*	*M*	*SE*	*M*	*SE*
Facial expressions	Left	98.86	0.37	98.69	0.41	98.43	0.51
	Right	98.51	0.36	97.73	0.52	98.25	0.42
Words	Left	98.69	0.45	98.53	0.47	98.60	0.37
	Right	97.90	0.44	98.73	0.44	98.69	0.44
Vocalizations	Left	98.22	0.43	97.47	0.50	98.34	0.44
	Right	98.20	0.51	97.20	0.51	97.47	0.67

Note: *M* = Mean; *SE* = Standard Error.

An association between emotion and space was observed when testing both axes, showing that positive (*vs.* negative) stimuli elicited faster responses to upper/right targets, and negative stimuli elicited faster responses to lower/left targets. When testing both axes separately (following previous studies – Damjanovic & Santiago, 2016; Gozli et al., 2013; Xie et al., 2015), a significant interaction between emotion and space emerged in the vertical axis only, consistent with our hypothesis and with previous observations (Damjanovic & Santiago, 2016; Gozli et al., 2013; Marmolejo-Ramos et al., 2013; Xie et al., 2015) that the vertical axis is more salient than the horizontal one in capturing this association. It should be noted, however, that the absence of an interaction between emotion and space in the horizontal axis may be due to the lack of statistical power, since a medium effect size ($\eta_p^2 = .038$) was observed even in the absence of a significant effect. It is possible that a similar association exists in the horizontal axis but is weaker than in the vertical axis, requiring more data for the effect to reach statistical significance. Moreover, as participants were simply asked to pay attention to the affective stimuli, i.e. there was no explicit valence categorisation or valence/hand-side response mapping (contrary to prior studies – de la Vega et al., 2012; de la Vega et al., 2013; Kong, 2013), task instructions may represent another plausible explanation for the absence of a significant interaction between valence and target location in the horizontal axis. Still, considering that an interaction between prime valence and target location was observed in the vertical axis, with a medium effect size, and with the same number of participants as in the horizontal axis, we can conclude that the vertical axis captures more effectively the relationship between emotion and space compared to the horizontal one (Damjanovic & Santiago, 2016; Gozli et al., 2013; Marmolejo-Ramos et al., 2013; Xie et al., 2015).

The observed emotion-space interaction in the vertical axis is consistent with previous evidence showing that positive (*vs.* negative) stimuli facilitate the discrimination of upper targets (Gozli et al., 2013; Montoro et al., 2015; Xie et al., 2015). Moreover, the observed congruency effect emerged in the absence of an explicit valence categorisation task, which indicates that the emotion-space association is partially automatic in the vertical axis (Gozli et al., 2013; Marmolejo-Ramos et al., 2013; Meier & Robinson, 2004). This is a relevant finding as previous studies failed to observe such effect when participants were not instructed to explicitly process stimulus valence (de la Vega et al., 2012; Montoro et al., 2015).

4.1. Faster positive/upper detection in the vertical axis: irrespective of stimulus type?

Overall, the congruency effect was found for all stimulus types, even though a closer inspection of reaction times revealed that this effect was enhanced in the case of vocalizations. Since the vocal stimulus set did not differ regarding pitch, such effect cannot be explained by the SPARC/SMARC effect (Rusconi et al., 2006).

Both affective facial expressions and nonverbal vocalizations are considered motivationally salient stimuli that engage an individuals' attention in an automatic way (Hawk et al., 2009; Liu et al., 2012; Pell et al., 2015). When processing facial expressions, individuals mostly rely on horizontal information provided by the face to identify the underlying emotion (Huynh & Balas, 2014). As the emotion-space association is believed to emerge from an individual's past experiences (Lakoff & Johnson, 1980), it is plausible that affective facial information is more strongly associated with horizontal space representations (Kong, 2013). Contrary to the current study, Kong (2013) used a response mapping relating valence to hand-side and found that participants were faster at discriminating positive (*vs.* negative) facial expressions when responding with their dominant (*vs.* non-dominant) hand. The null effect that we found in the horizontal axis suggests that even when using stimuli more strongly associated with the horizontal space, other conditions (e.g. explicit valence-side response mapping) should be met for the association to emerge horizontally (de la Vega et al., 2012).

Perhaps one of the most relevant aspects of our study is that it supports the observation of an emotion-space association in the auditory domain (Montoro et al., 2015), and in the absence of linguistic information. While Montoro and collaborators observed that spoken words elicited a congruency effect, they also observed that this effect was strongly dependent on valence categorisation, which stands in contrast with the current results. However, it should be noted that Montoro et al. (2015) used vocal stimuli with verbal content, whereas we used nonverbal affective vocalizations. It is possible that semantic information may require more processing resources for an emotion-space association to emerge (Montoro et al., 2015), whereas this association may be more automatic in the case of nonverbal affective vocalizations (Liu et al., 2012; Pell et al., 2015), as supported by previous studies (Cattaneo et al., 2014).

4.2. Faster positive/upper detection in the vertical axis: a spatial bias?

An additional analysis was performed, in which reaction time data for neutral stimuli were subtracted from reaction time data for affective stimuli, allowing to rule out a possible spatial bias in favour of one of the two locations. This analysis kept with the same results of the main analysis: faster responses for targets presented at upper/right locations, when preceded by positive stimuli; faster responses for targets presented at upper locations, when preceded by positive stimuli in the vertical axis; no significant interaction between emotion and space in the horizontal axis. Such results suggest that the observed effects are not due to an overall preference for a certain response key or a target location, which is further supported by the absence of a significant effect of target location. Even if we consider the hypothesis that such effect only emerged due to an additive effect related to response mapping (i.e. responding "up" with a key in an upper location using the right hand), previous studies demonstrated that this type of mapping is not a requirement for an emotion-space association effect to be observed in the vertical axis (Montoro et al., 2015).

4.3. Faster positive/upper detection in the vertical axis: reaction times but not accuracy?

In line with our hypothesis, the association between emotion and space was not reflected in accuracy data, but only in reaction times (Montoro et al., 2015; Xie et al., 2015). Further, it does not seem to be accounted for by a trade-off effect between reaction times and accuracy rates (de la Vega et al., 2013). If this was the case, the opposite pattern should have been observed in the case of accuracy rates, i.e. lower accuracy rates for congruent compared to incongruent conditions. The strongest effects on reaction time data may be explained by the short cue-target interval (< 250 ms) used in the current study, which followed Xie et al. (2015). As previously mentioned, short intervals may prevent the decoding of spatial information from the affective stimulus (i.e. cue), and consequently accuracy is not improved (van Ede et al., 2012). However, reaction time effects may still emerge, as observed in our study: as cue information was retrieved after target presentation, the expected and actual target location could be compared, resulting in improved reaction times in congruent conditions (positive/upper and negative/lower; van Ede et al., 2012). However, it may also be the case that the absence of an effect results from the characteristics of the affective stimulus in relation to the target location (Bonato et al., 2016). As in the study of Xie et al. (2015), the affective cues that preceded the targets did not contain any information regarding the possible location of the target. As shown in previous studies (Bonato et al., 2016; Prinzmetal et al., 2005), the cue that precedes the target should be informative of its location for accuracy effects to emerge, otherwise a null effect is observed (Montoro et al., 2015; Ouellet et al., 2010; Xie et al., 2015). It should be also noted that the absence of an accuracy effect may be a consequence of the task used in the current study, as participants' performance was close to a ceiling level, in both congruent and incongruent trials.

4.4. Faster positive/upper detection in the vertical axis: conceptual metaphor or polarity correspondence?

Besides the emotion-space association, another possible explanation for the current results is the polarity correspondence principle (Lakens, 2012; Proctor & Cho, 2006). According to this principle, in binary choice reaction tasks participants categorise different conceptual (e.g. valence) and perceptual (e.g. stimulus location) dimensions as either being "+polar" or "−polar". Conditions with a correspondence of positive polarities (positive/upper) will show a processing benefit (reflected in shorter reaction times) compared to conditions with a correspondence of negative polarities (negative/lower; Lakens, 2012). In the current study, shorter reaction times were observed for positive/upper conditions, and for negative/lower conditions compared to conditions with no polarity correspondence (i.e. negative/upper and positive/lower). Moreover, the interaction between target location and valence did not reach significance in the horizontal axis, when tested separately. We believe that the current results are better explained by the emotion-space association than by the polarity correspondence principle, for two reasons. First, according to the latter principle, we would expect an additional significant effect in the horizontal axis, considering that target locations and response mappings would be also categorised along binary dimensions: both right location and right response key would be categorised as "+polar", since all participants included in the analysis were right-handed. Second, according to the summation of polarity effects, the condition of "−polar" affective words preceding an upper or lower target should be associated with longer reaction times than lower targets preceded by "+polar" affective stimuli (Lakens, 2012). None of these possibilities was observed in the current study. However, while we believe that the emotion-space association provides a better explanation for the current results, our experimental design does not allow fully disentangling the conceptual and cognitive mechanisms that underlie the observed effects. Hence, more studies should be conducted (e.g. in which binary categorisation is not possible) to probe whether the emotion-space association still emerges.

Together, the current results support the idea that the emotion-space association is not restricted to a single sensory modality (Montoro et al., 2015) or to stimuli with semantic content (Cattaneo et al., 2014; Damjanovic & Santiago, 2016; Kong, 2013). The congruency effect in the vertical axis seems to be better accounted for by a conceptual metaphor between emotion and space (Lakoff & Johnson, 1980). Nonetheless, the presence of an effect even when using nonlinguistic stimuli does not imply that such interaction is not modulated by language (Goodhew et al., 2014). Further studies are required to fully understand the conditions in which the emotion-space association emerges, the degree of attention that it requires, and how it differs across tasks.

4.5. Limitations and future directions

One of the aims of the current study was to test the emotion-space association without explicitly instructing participants to categorise the valence of the affective stimuli, though ensuring that they still payed attention to those stimuli. Thus, a memory task including the affective stimuli was performed, and only participants whose mean accuracy score was higher than 60% were included in the analysis. This resulted in the loss of a substantial amount of data, which might be a consequence of the type of task used (a difficult task considering the number of stimuli to encode) and of the moment in which the task was administered (at the end of the experiment, when participants' fatigue might have been at its highest). In future studies, a less demanding task should be used, ensuring that while participants pay attention to the affective stimulus, the amount of data loss is reduced.

Moreover, future studies probing the emotion-space association should use a design in which more than two possible responses are available, such as the one reported by Gozli, Pratt, Martin, and Chasteen (2016). With an increase in the number of possible responses, a binary categorisation will not be allowed. Hence, if an association between emotion and target location is still observed, it will not be accounted for by polarity effects. Moreover, future studies should examine the potential effects of handedness by using a similar task to compare right- and left-handers, and by counterbalancing the response keys to ensure that the observed effects are due to the emotion-space association and are independent of response mapping (Casasanto, 2009).

It should be noted that the significant effects reported in the current study were obtained using a 1600 ms stimulus onset asynchrony (SOA), following the study of Xie et al. (2015), in which the same SOA elicited a more robust emotion-space association compared to longer SOAs. As we did not manipulate SOA, it is possible that a shorter SOA would have elicited better results. However, Montoro et al. (2015) found that participants' responses were faster for the positive/upper condition when using a 400 ms SOA compared to a 200 ms SOA. These results suggest that there might be an optimal SOA to elicit the emotion-space association, and that shorter is not always better. In future studies, SOA values should also be manipulated to examine whether there really is an optimal interval to elicit the emotion-space association.

5. Conclusions

Our study revealed a partially automatic emotion-space association in the vertical axis, which was independent of sensory modality. The close interactions between affective and spatial representations may facilitate how humans effectively communicate and understand affective states such as happiness ("He's in high spirits today").

Note

1. Even though we tried to use an equivalent number of male and female non-linguistic vocalizations, our stimuli set contained more female vocalizations as our main selection criterion involved choosing the vocalizations with the highest emotion recognition rates (female vocalizations presented higher recognition rates for the emotions – Vasconcelos et al., 2017). However, no significant effects were expected as a function of speaker's gender: Cattaneo et al. (2014) found no differences in line bisection when participants were listening to a female *vs.* male vocalization.

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No potential conflict of interest was reported by the authors.

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Contributors

Maria Amorim and Ana P. Pinheiro developed the study concept and design. Maria Amorim collected the data. The two authors collaborated in data analysis and in writing the first draft of the manuscript. They equally contributed to and have approved the final version of the manuscript.

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Appendix

Table A1. Stimuli included in the analysis.

File name	Stimulus type
AF01NES	Facial Expression
AF02NES	Facial Expression
AF03NES	Facial Expression
AF04NES	Facial Expression
AF05HAS	Facial Expression
AF05NES	Facial Expression
AF06HAS	Facial Expression
AF06NES	Facial Expression
AF07HAS	Facial Expression
AF07NES	Facial Expression
AF08HAS	Facial Expression
AF09DIS	Facial Expression
AF09NES	Facial Expression
AF11HAS	Facial Expression
AF12DIS	Facial Expression
AF13AFS	Facial Expression
AF13NES	Facial Expression
AF14AFS	Facial Expression
AF14ANS	Facial Expression
AF16AFS	Facial Expression
AF17SAS	Facial Expression
AF18HAS	Facial Expression
AF19NES	Facial Expression
AF20HAS	Facial Expression
AF21DIS	Facial Expression
AF21HAS	Facial Expression
AF22AFS	Facial Expression
AF22ANS	Facial Expression
AF22HAS	Facial Expression
AF23ANS	Facial Expression
AF25HAS	Facial Expression
AF26HAS	Facial Expression
AF26NES	Facial Expression
AF29NES	Facial Expression
AF32SAS	Facial Expression

(*Continued*)

Table A1. Continued.

File name	Stimulus type
AF33HAS	Facial Expression
AF34HAS	Facial Expression
AF34NES	Facial Expression
AM01NES	Facial Expression
AM02NES	Facial Expression
AM03NES	Facial Expression
AM05ANS	Facial Expression
AM05HAS	Facial Expression
AM05SAS	Facial Expression
AM06HAS	Facial Expression
AM06NES	Facial Expression
AM07HAS	Facial Expression
AM07NES	Facial Expression
AM08NES	Facial Expression
AM09HAS	Facial Expression
AM09NES	Facial Expression
AM10ANS	Facial Expression
AM10NES	Facial Expression
AM11AFS	Facial Expression
AM11ANS	Facial Expression
AM11NES	Facial Expression
AM12DIS	Facial Expression
AM12HAS	Facial Expression
AM13HAS	Facial Expression
AM13NES	Facial Expression
AM14AFS	Facial Expression
AM14NES	Facial Expression
AM16SAS	Facial Expression
AM17HAS	Facial Expression
AM17SAS	Facial Expression
AM20HAS	Facial Expression
AM22HAS	Facial Expression
AM23HAS	Facial Expression
AM24DIS	Facial Expression
AM25AFS	Facial Expression
AM25HAS	Facial Expression
AM25NES	Facial Expression
AM26HAS	Facial Expression
AM31DIS	Facial Expression
AM31NES	Facial Expression
AM32HAS	Facial Expression
AM32SAS	Facial Expression
ABRAÇO	Word
ALEGRE	Word
AMADO	Word
ARMARIO	Word
ASSENTO	Word
BEIJO	Word
CACIFO	Word
CAMIÃO	Word
CARICIA	Word
CESTO	Word
CIRCULO	Word
COLERA	Word
COMEDIA	Word
COSTUME	Word
CRIANÇA	Word
FAMILIA	Word
FEDOR	Word
FERIADO	Word
FERIAS	Word
FERRO	Word
FESTA	Word

(*Continued*)

Table A1. Continued.

File name	Stimulus type
FESTIVO	Word
FUNERAL	Word
FUNGO	Word
GANCHO	Word
GENIAL	Word
GLACIAR	Word
HABITO	Word
HORROR	Word
HUMOR	Word
INFELIZ	Word
LARVA	Word
LENÇO	Word
LINDA	Word
LOUCO	Word
MEDROSO	Word
MENDIGO	Word
MENTIRA	Word
METAL	Word
MISERIA	Word
MOLDE	Word
NATAL	Word
PANICO	Word
PARTE	Word
PATENTE	Word
PERIGO	Word
PIADA	Word
PIOLHOS	Word
PODRE	Word
PORTA	Word
PRAIA	Word
PRAZER	Word
PRENDA	Word
QUEIXO	Word
RECADO	Word
ROCHA	Word
ROLHA	Word
SECADOR	Word
SOMBRA	Word
SONHO	Word
SORRISO	Word
SORTE	Word
SUCESSO	Word
TIGELA	Word
TINTA	Word
TORTURA	Word
TRAIDOR	Word
TRISTE	Word
TUBARÃO	Word
TUMOR	Word
ULTRAJE	Word
VERDADE	Word
VIDRO	Word
VITORIA	Word
VOMITO	Word
42_ neutral ***	Vocalization
42_ pain	Vocalization
42_happiness	Vocalization

(*Continued*)

Table A1. Continued.

File name	Stimulus type
45_ anger	Vocalization
45_ disgust	Vocalization
45_ fear	Vocalization
45_ happiness	Vocalization
45_neutral***	Vocalization
45_pain	Vocalization
45_sadness	Vocalization
46_ happiness	Vocalization
46_ neutral ***	Vocalization
46_disgust	Vocalization
46_fear	Vocalization
53_ disgust	Vocalization
53_ fear	Vocalization
53_ happiness	Vocalization
53_ neutral ***	Vocalization
53_ pain	Vocalization
53_ sadness	Vocalization
55_ disgust	Vocalization
55_ happiness	Vocalization
55_ neutral ***	Vocalization
55_ pain	Vocalization
55_anger	Vocalization
58_ anger	Vocalization
58_ happiness	Vocalization
58_ neutral **	Vocalization
58_ sadness	Vocalization
59_ anger	Vocalization
59_ happiness	Vocalization
59_ neutral **	Vocalization
6_ fear	Vocalization
6_ happiness	Vocalization
6_ neutral ***	Vocalization
6_ sadness	Vocalization
60_ disgust	Vocalization
60_ fear	Vocalization
60_ happiness	Vocalization
60_ neutral **	Vocalization
60_ pain	Vocalization
60_ sadness	Vocalization
61_ anger	Vocalization
61_ neutral **	Vocalization
61_ sadness	Vocalization
achievement_M_7	Vocalization
amusement_C_1	Vocalization
amusement_C_2	Vocalization
amusement_C_3	Vocalization
amusement_C_4	Vocalization
amusement_M_5	Vocalization
amusement_M_6	Vocalization
amusement_MS_10	Vocalization
amusement_MS_11	Vocalization
amusement_MS_8	Vocalization
amusement_MS_9	Vocalization
amusement_T_12	Vocalization
amusement_T_13	Vocalization
amusement_T_14	Vocalization
amusement_T_15	Vocalization
amusement_T_16	Vocalization

Notes: * indicates number of repetitions.