Clouded Judgments? The Role of Virtual Weather in Word Valence Evaluations

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Abstract

Exploring the dynamic interface of environmental psychology and psycholinguistics, this investigation delves into how simulated weather conditions —sunny versus rainy— affect emotional perceptions of linguistic stimuli within a Virtual Reality (VR) framework. Participants assessed words' emotional valence being exposed to these distinct environmental simulations. Contrary to expectations, we found that while rainy conditions modestly prolonged response times, they did not significantly alter the emotional valence attributed to words. Our study shows that weather can affect emotional cognition, but intrinsic emotional word properties are resilient to environmental influences. This highlights the complex interplay between environmental factors and linguistic processing and reaffirms the importance of environmental contexts in cognitive and emotional evaluations, especially in the face of climate change. By integrating VR technology with environmental psychology and linguistics, our research offers novel insights into the subtle yet significant ways in which virtual and real-world environments converge to shape human emotional and cognitive responses.

Keywords: Virtual Reality, Emotion, Valence Rating, Weather Conditions

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Emotions can be understood as stemming from an individual's awareness of physiological changes within the body, an idea first proposed by James (1884). Adding to this, Northoff (2012) emphasized the environment as an essential component, arguing that emotions and emotional feelings are the outcome of the dynamic interaction among the brain, body, and environment. This perspective underscores the multifaceted nature of emotions and their profound impact on our thoughts, perceptions, and interactions with the world (Dolan, 2002; Zajonc, 1984). Additionally, the intricate relationship between emotion and language is evident, where emotion serves both as a means of expression and a tool for perceiving feelings, including their associations with specific objects, traits, and actions (Hinojosa et al., 2020).

In the study of human emotions and their relationship with language, valence, and mood state are important concepts to be accounted for. While often seen as interconnected, these concepts serve distinct roles in our emotional landscape. For instance, valence refers to one of the dimensions across which the emotional value of stimuli can be measured, ranging from pleasant to unpleasant, and that significantly influences our perception and response to linguistic elements (Stadthagen-Gonzalez et al., 2017). Valence has long been a fundamental approach in the study of emotional dimensions (Kensinger & Schacter, 2006).

In recent years, concerning language, numerous studies have focused on the assessment of valence through the human rating of thousands of specific words (e.g., Stadthagen-Gonzalez et al., 2017). However, these efforts appear limited given the vast number of words in a language that remain unexplored. Consequently, researchers have turned to computational methods where subjective ratings for uncategorized words can be estimated based on their co-occurrence with related words within text corpora (see Betancourt et al., 2023; Buades-Sitjar et al., 2021; Planchuelo, Buades-Sitjar, et al., 2022; Planchuelo et al., 2024).

In contrast to valence, mood represents a continuous and overarching emotional state that shapes an individual's behavior (i.e., facilitating emotional externalization) and perceptions. It possesses a long-lasting, diffuse, non-specific nature—as it reflects the cumulative effect of a variety of stimuli— and can persistently influence our experiences and interactions (Eldar et al., 2016; Sekhon & Gupta, 2023). Therefore, mood can affect how we perceive the valence of linguistic material (Akram et al., 2020). Furthermore, given that mood is not tightly related to a specific stimulus and takes place on a longer time scale (Beedie et al., 2005; Eldar et al., 2016), the question of how we perceive the valence of linguistic material under sudden changes in our environmental context remains open.

Affective variables significantly impact our cognition across different dimensions, influencing lexical processing (Kuperman et al., 2014), short and long-term recall (Talmi et al., 2007), and attention (Mathewson et al., 2008). However, while the processing of emotional stimuli is deeply intertwined with human cognition and subject to variability due to individual differences, there are broader variables that influence all individuals. Good examples of this phenomenon can be observed within the frame of momentary and transient unexpected social-context changes (e.g., the COVID confinement measures, see Kyröläinen et al., 2022; Planchuelo, Baciero, et al., 2022 for evidence of altered emotional judgments for COVID-19-related words).

Meteorological weather is one of those external or contextual factors that has been proposed as a key modulator of cognitive and emotional status. Prior research has demonstrated a significant link between weather conditions on both emotional state and cognitive performance. For instance, sunny weather is often linked with positive emotional states and enhanced cognitive abilities, whereas gloomy conditions tend to correlate with negative emotional states (Keller et al., 2005). While a common belief holds that sunny weather promotes happiness and rain leads to melancholy, these effects may be more accurately attributed to prolonged exposure to such weather conditions and the interaction between season and temperature (L. Zhang et al., 2023). In this line, prolonged exposure to a certain meteorological condition might influence mood, leading to more sustained emotional states, whereas transient and sudden changes in weather conditions (e.g., sudden rain on an otherwise dry day), could be expected to have an impact on valence—a more immediate, moment-to-moment evaluation of emotional experiences.

Such understanding sets the stage for considering the broader implications of environmental effects on our psychological well-being and cognitive processes. In this context, Fredrickson's broaden-and-build theory offers a compelling lens through which emotional responses elicited by different weather conditions could be examined. According to the theory, positive emotions broaden individuals' momentary thought-action repertoires, building enduring personal strategies leading to different beneficial outcomes such as improved well-being, increased resilience, and enhanced problem-solving abilities (Fredrickson, 2004; Fredrickson et al., 2003, 2008). This broadening effect contrasts with the narrowing influence of negative emotions, which are typically associated with specific behavioral responses like fight or flight (Fredrickson, 2004). Therefore, in the context of weather changes, this theory could help us hypothesize different emotional responses elicited by different meteorological conditions. For instance, sunny weather could broaden individuals' attention and cognition, thereby facilitating higher valence ratings on words due to the expansive nature of positive affect. Conversely, rainy weather might induce lower valence ratings on words, as it may not elicit the same level of positive emotional response, potentially narrowing individuals' thought-action repertoires. This approach aligns with different research indicating that weather conditions can significantly affect decision-making and risk-taking behaviors (Costa Sperb et al., 2022; Li et al., 2024).

Nonetheless, other studies have suggested that the relationship between emotional states and weather conditions is likely to be idiosyncratic (Jiang et al., 2022; Klimstra et al., 2011) and that weather might be operating over our behavioral responses by limiting our cognitive performance through other paths. For instance, cold weather has been shown to impact our ability to focus (Park et al., 2020; Taylor et al., 2016). Moreover, physiological responses to weather, such as increased serotonin production and enhanced vitamin D synthesis due to sunlight exposure, have both been linked to cognitive function (van der Schaft et al., 2013). Given these findings, the link between weather conditions and human emotion and cognition stands multifaceted, with effects that may not manifest universally across individuals, particularly in the short term.

The potential influence of adverse weather conditions on behavior has sometimes been explained in terms of reduced processing fluency. The more perceptually fluent a stimulus is, such as a clear and easily visible item, the more precise judgments can be made about it (Oppenheimer & Frank, 2008). Consequently, the experience of disfluency, described as the metacognitive perception of difficulty in processing information (Alter et al., 2007), has been shown to shift the way humans process stimuli (Oppenheimer, 2008). In this line, when weather conditions degrade visibility —similar to making the font size smaller or blurring visual input— it seems plausible that cognitive processing experiences a form of "metaphoric fog", engaging more analytical and less intuitive processes (Oppenheimer, 2008), requiring processing adaptations to face the processing of disfluent material. Thus, the influence of weather could extend beyond mere emotional responses, permeating physiological, psychological, and cognitive domains as well.

Building on this understanding of the role of environmental variables, preceding research has shown how context modulates emotional evaluations. In this line, Bazzi et al. (2022) and Tapia et al. (2024) showed that once a stimulus is contextualized whether by creating a social setting (e.g., describing an individual's situation) or creating an accessible mental exemplar (e.g., making participants experience something never experienced before), the subsequent emotional judgments can change. Similarly, Escobar et al. (2021) showed that lower temperatures (e.g., the visual representation of a thermometer displaying a cold temperature) are associated with negative-valence emotions. This association extends to linguistic contexts as well, where words like "cold" are implicitly linked to negative-valenced emotional adjectives. Similarly, research consistently indicates that the context of stimulus presentation significantly influences its perception and emotional evaluation, underscoring the complex interplay between context and the perceived valence of stimuli (Barrett et al., 2011; Barrett & Kensinger, 2010). For instance, Aviezer et al. (2008) showed that the valence judgment of a facial expression changes depending on the body posture that accompanies the expression. Similarly, Liu et al. (2019) demonstrated how language as a context biases the emotionality of neutral faces, and Pazda et al. (2024) showed that the colorfulness of a photography modulates its perceived valence, with colored photographs being perceived as happier than photographs in black and white.

Considering the complex interplay between contexts, emotional perceptions, and linguistic processing underscored by prior research, the extent to which transient weather conditions influence valence ratings of words remains unclear, possibly due to the difficulty associated with recreating comparable experimental conditions in laboratory settings. Virtual Reality (VR) technology has emerged as a powerful tool for simulating real-world conditions in a controlled setting, allowing researchers to delve deeper into understanding the interactions between the environmental context and cognition (Rocabado et al., 2022; Shin et al., 2021). By creating immersive virtual environments, researchers can control the variables at play, thus obtaining more accurate insights into human behavior and cognition (Rocabado & Duñabeitia, 2022). Within this framework, the current study aims to directly investigate how simulated weather conditions influence the valence ratings of words. We were particularly interested in understanding how two distinct weather scenarios (namely, sunny and rainy) affect the valence ratings of words of different polarities (i.e., positive and negative). Within the controlled and immersive environment offered by VR, participants were exposed to realistic simulations of these weather conditions, thereby allowing us to observe potential shifts in their emotional evaluations. In sum, incorporating elements from environmental psychology, linguistics, and advanced technology, our study seeks to elucidate if immediate environmental conditions, specifically weather, alter the emotional evaluation of linguistic material.

Methods

Participants

G*Power (Faul et al., 2007) was used to estimate the sample size needed to capture an estimated large effect size (w = 0.35; 1-β = 0.80), with a study design of one group and two predictors (valence and weather condition). Thus, at least 31 participants would be needed. A total of 36 university students and employees from Nebrija University took part in the experiment, all of them being native Spanish speakers, participated in this study in exchange for a monetary incentive. They all had normal or corrected-to-normal visual acuity and hearing. None showed cognitive impairments in the Cognitive Assessment Battery (CAB) PRO (CogniFit Inc., San Francisco, CA). 25 participants self-identified as female (Mage= 24.2, SD= 10.24) and 11 participants self-identified as male (Mage= 24.46, SD= 3.91).

Participants were granted written informed consent for their participation. The experimental procedures were approved by the Research Ethics Committee at Nebrija University (approval code UNNE-2022-0017).

Materials

From the Stadthagen-Gonzalez et al. (2017) affective norms database, we selected 250 emotional words. The target materials comprised 100 positive and 100 negative words, and 50 neutral words were also added as fillers to avoid biasing the judgments. Different t-test analyses showed that the two sets of target words were statistically different from each other in terms of their valence, $t(198)=64.04$, $p<.001$. Additionally, the two sets of words were controlled for other relevant dimensions (i.e., arousal: $p=.305$; word frequency: $p=.614$; word length: $p=.271$; see Table 1 and Supplementary Materials). The filler-neutral words were also matched in word frequency and word length to the target items. Two experimental lists were created using half of the stimuli from each condition and they were randomly associated with the two weather conditions (i.e., sunny and rainy), so that each item appeared only once in the whole session, but in a different condition across participants. Item presentation order was fully randomized across participants, and weather conditions were assigned in a counterbalanced order between participants, mitigating potential biases from the presentation order.

[Table_1]

Virtual Reality setting

The stimuli were presented in a virtual reality setting using a head-mounted display (HMD). A main 3D open town square was used. This main scenario consisted of a 3D representation of a typical Spanish rural *plaza*. Our choice was primarily driven by the quality, in terms of realism, of the main 3D model. Additionally, it allowed us to place participants in an open and familiar open and unprotected space where they could experience simulated weather, thereby facilitating a sense of presence.

In a central part of our scenario, a black street billboard with a white background was embedded with the Vizard inspector tool. This element was implemented for item presentation purposes. Finally, to improve participants' immersiveness and sense of presence, the virtual reality environment was accompanied by similar levels of ambient noise in both weather conditions. Rain sounds were added to the rainy condition, while the sunny condition included background sounds of a fountain and the cooing of pigeons. Moreover, an animated background sky was included (see Figure 1, for a visual demonstration of the environment, see Supplementary Materials for a video demonstration).

[Figure_1]

Apparatus

The virtual reality task was programmed in Python 2.7 and designed using Vizard 6. All 3D environments and experiment-related content were displayed through the HTC VIVE Pro HMD, at a rendering resolution of 2880×1600 pixels (1440×1600 pixels per eye). The built-in display offers a 90-Hz refresh rate and a 110º field of view. Crucially, throughout the experiment, participants' viewpoints within the VR environment were consistently anchored regardless of the position changes participants could adopt in the real world.

Task and procedure

Participants were seated on a rotating chair and equipped with the HMD, immersing them in a three-dimensional virtual environment that enabled a full 360º view from a stationary perspective. Once the headset was placed and calibrated, participants were given the two controllers, represented as virtual hands within the VR environment. Before starting the valence rating task, explicit instructions were displayed on a floating canvas. The items to be rated were displayed centrally on a virtual street billboard, ensuring readability. They were presented in black using the Courier New monospaced font.

The instructions were the same as those in the Spanish adaptation of Affective Norms for English Words (ANEW) by Redondo et al. (2007). Participants rated the valence of each word on a 9-point scale, ranging from 1 (unhappy) to 9 (happy), with 5 being neutral. They were advised to rely on initial impressions. In each trial, the word to be rated and the rating scale appeared concurrently. A central fixation point prefaced each trial for 500ms, and the word remained visible until a response was registered.

Results

All the data were curated and processed using R (R Core Team, 2022) within the RStudio environment. Data wrangling was performed using R to remove confidential information and to assess data quality. This involved verifying that each participant experienced both weather conditions and that the number of items responded to was consistent across all participants. The final dataset was created through this process and was used for analysis. Analyses focused on the responses to the target stimuli (namely, the positive and negative words). Nonetheless, an additional analysis of the neutral items was also performed[1]. Responses that took longer than 3000ms were excluded from the analysis

[1] This analysis was run separately per request of an anonymous reviewer given that these items were initially selected as fillers and the number of stimuli did not match that of the items in critical conditions.

(7.25% of the data). A descriptive analysis was performed on participants' ratings and response times (see Table 2 and Figure 2).

[Table_2 and Figure_2]

Response Time

Reaction Time data were analyzed through linear mixed-effects modeling in Jamovi (The jamovi project, 2022) using the GAMLj module (Gallucci, 2019). The analysis model included Response Time as a dependent variable (n=6,678 observations, 3,349 in the sunny condition and 3,329 in the rainy condition), and it included a fixed-effects structure consisting of the two-level factors Weather Condition (Sunny|Rainy) and Valence Condition (Positive|Negative), as well as their interaction. The model's random structure included random intercepts for Participants and Items[2].

The main effect of Weather was significant, $F(1, 6498.9)=19.96$, $p<0.001$, with response times being longer in rainy weather conditions. Similarly, a main effect of Valence manipulations was found, $F(1, 57.9)=4.86$, $p=0.031$, with response times associated with negative items being larger than in the case of positive stimuli. Finally, the interaction between the two factors was not significant, $F(1, 6507)=0.30$, $p=0.584$ (see Figure 2).

The analysis model of the neutral stimuli included a total of 1,642 observations (827 in sunny conditions and 815 in rainy conditions) and it had a similar structure to the main analysis, except for the Valence factor. Results showed no significant effect of Weather on reaction times, $F(1, 1582)=0.93$, $p=0.335$ (see Figure 2).

Valence ratings

A linear mixed-effects model was used to analyze the valence rating data related to word stimuli. The model had Valence Ratings as a dependent variable and included the same fixed- and random-effects structure used in the RT analysis.

[2] Considering that gender differences in emotional processing have been consistently reported in the literature (Deng et al., 2016; Donges & Suslow, 2017), we opted for including this factor in the structure.

The main effect of Weather was not significant, F(1, 6433.7)=1.42, p=0.234. As expected, a significant main effect of Valence was found, F(1, 61)=363.94, p<0.001, being positive words rated higher compared to negative ones. The interaction between the two factors was not significant, F(1, 6431.6)=1.33, p=0.249 (see Figure 2).

The analysis model of the neutral filler trials followed the same rationale and showed a significant effect of Weather, F(1, 1573)=4.41, p=0.036, with the neutral words presented under sunny conditions being rated higher compared to negative ones (see Figure 2).

Contingency analysis of positive and negative valence ratings

Considering the results reported in Figure 2, suggesting potential differences in how the rating data were distributed across weather conditions, we conducted a Chi-Square test to examine the distribution of the proportions of ratings among the different levels of the rating scale for each weather condition in each group of words (i.e., positive and negative). The analysis of the positive words showed a highly similar distribution across weather conditions, χ^2 (8, n=3329)=7.00, p=0.537, Cramer's V=0.046 (see Figure 2). The Chi-Square test conducted to examine potential differences in the distributions between negative valence rates and weather conditions showed a significant difference, χ^2 (8, n=3329)=16.2, p=0.040, Cramer's V=0.070, with somewhat higher proportions of ratings in the higher levels of the rating scale for negative words rated in rainy environments than in sunny ones.

Discussion

The present study delved into the intricate intersection of environmental psychology and psycholinguistics, aiming to discern the potential influence of simulated weather conditions on emotional perceptions of linguistic stimuli within the controlled environment of Virtual Reality (VR). Drawing upon previous research that highlighted the interplay between weather conditions and emotional states (e.g., Keller et al., 2005; Kööts et al., 2011) and the potential mediating role of disfluency (Dreisbach et al., 2018; Oppenheimer, 2008; Reber et al., 2004), in the current study a realistic simulation of two distinct weather scenarios (namely, sunny and rainy) was designed. The main goal was to ascertain how these environmental conditions might modulate emotional perception and evaluations of words' valence.

The main results comparing positive and negative words suggested an interesting dynamic: rainy weather conditions, while associated with slower responses, did not notably shift the emotional evaluations of words' valence. Furthermore, while the advanced setting of VR permitted controlled and realistic exposure, the influence of the simulated weather on emotional judgments was less pronounced than one could have initially anticipated. In contrast, as expected, the inherent polarity of the valence of the stimuli played a more pronounced role, influencing both response times and emotional judgments. This observation aligns with previous studies emphasizing the foundational role of emotion in shaping our interactions with linguistic stimuli (Dolan, 2002; Hinojosa et al., 2020).

An additional analysis of the neutral (filler) words also revealed interesting results. Although no differences were found in response times, sunny weather conditions were found to be prone to higher valence ratings for neutral words. While these findings present a contrastive pattern compared to the effects found for positive and negative words, they should be interpreted with caution. It is important to note that the words originally intended to be neutral were only used as fillers, resulting in a smaller sample size compared to the positive and negative words. Although most of the intrinsic characteristics of the neutral words match those of the rest, they differ in terms of arousal. The impact of arousal on how we process emotional stimuli is crucial. It not only increases physical readiness and attention, but it also affects cognitive responses. This leads to differences in processing speed and engagement levels, which can significantly impact reaction times and decision-making in different situations (Barriga-Paulino et al., 2022; Citron et al., 2016; Larsen et al., 2008; D. Zhang et al., 2014). Therefore, it is crucial to carefully balance all linguistic variables in future studies to reduce any potentially confounding factor.

Building upon the concept of cognitive disfluency, rainy weather-related valence ratings predominantly influenced word identification and processing, as suggested by the main effect found in the latency data. In a recent study, Rocabado et al. (2023, under review) utilized an experimental setting identical to the current experiment, with the same weather conditions. They showed the existence of a nuanced interplay between simulated weather and visual word identification, demonstrating that word processing involved an additional reading cost in rainy conditions. Their results endorse the idea that environmental factors significantly influence visual processing of printed items at a lexical level. Altogether, the preceding results and the current ones suggest that the differences in response times to items presented in sunny and rainy conditions might be a direct consequence of the perceived visual degradation of the quality of the stimuli presented under rainy conditions. While the effect in accessing lexical representations seems clear, the lack of such an impact in the emotional assessment could be at least partially explained by previous research showing that the influence of emotional states on language appears to come from post-lexical integrative mechanisms (Chwilla, 2022). In this line, Havas et al. (2007) showed that emotional context affected the comprehension speed of emotionally valenced sentences but did not impact the processing speed of polarized emotional words on lexical decision tasks.

As seen, the main analysis of valence ratings yielded no significant differences as a result of weather conditions when comparing positive and negative words. The analysis failed to reveal a substantial main effect of weather, while not surprisingly, a significant main effect of valence was identified, with positive words consistently receiving higher ratings compared to negative words. In the full absence of a main effect of weather or an interaction between the factors, it can be concluded that no discernible variations in emotional judgments, as measured by valence ratings, were associated with the different simulated weather conditions in the study. Nonetheless, a post hoc analysis considering the distribution of responses suggested slight differences in the polarization of the rating for negatively-valenced items. Overall, these results could be taken as an indication that the relationship between weather conditions and the evaluation of emotional content is negligible or minimal. However — although unintended— results from the supplementary analysis of the neutral filler words showed differences depending on the context they were presented in. This result aligns with previous evidence showing that the processing of neutral stimuli is context-dependent and as such, easy to bias (Romero-Ferreiro et al., 2018; Tae et al., 2020). Furthermore, these results support the belief that sunny weather conditions are associated with higher valence or positive emotions, therefore broadening individuals' thought-action repertoires and biasing participants ratings accordingly, although in the current experiment this exclusively occurred for neutral words (Fredrickson, 2004).

While sentiment analysis of social media posts suggests that optimal weather conditions evoke positive emotional states and that less ideal weather conditions lead to negative emotional states (Baylis et al., 2018; Jiang et al., 2022), our results show that the emotional evaluation of word stimuli is not modulated by environmental context variables. This concurs with a recent study that underscores the multifaceted nature of environmental influences on emotional evaluations, with temperature and seasonal variations playing a nuanced role in emotional evaluations (Behnke et al., 2021). However, the interplay between weather conditions and emotional valence, as observed in real-world settings like travel scenarios, underscores the potential for external environmental factors to modulate emotional responses, depending on how these were experienced (e.g., being outdoors or indoors) (Ettema et al., 2017; Klimstra et al., 2011). Thus, the minimal impact of simulated weather conditions on valence evaluations in our VR study suggests that the level of environmental realism and the context in which individuals engage with these conditions may significantly influence the extent to which weather can affect emotional valence and subsequent linguistic evaluations.

Finally, a note of caution is recommended when interpreting the current results. There's a likelihood that prior data obtained from human ratings of emotional factors were primarily gathered from student cohorts who would have been experiencing diverse real-world weather conditions at the time of the test. Consequently, it seems plausible to hypothesize that such authentic atmospheric influences could have interacted with, or even counteracted, the simulated weather conditions within our VR experiment. This underscores the complexity of accounting for emotional judgments in controlled environments when contextual factors associated with the large datasets typically used as normative data may not fully align with the intricacies of real-world experiences.

The presence of these external factors highlights the intricate challenge of arriving at definitive conclusions and underscores the nuanced interaction between genuine and simulated environments in shaping cognitive and emotional responses. Furthermore, recent research underscores the increasing significance of shifting weather patterns, driven by climate change, and their profound impact on human emotional well-being. Climate conditions resulting from the direct consequences of climate change have been linked to negative emotions and concerns (Iniguez-Gallardo et al., 2021). Therefore, it is crucial to acknowledge that while the influence of weather on word valence evaluation may be relatively modest, it should not be underestimated in the coming decades.

In summary, this study contributed to the field of affective neurolinguistics (see Hinojosa et al., 2020), providing evidence of the intricate interplay between real and virtual environments in shaping cognitive and emotional responses. Although the influence of weather on word valence evaluation in this context may have been relatively subtle, its enduring relevance within the domain of cognitive science of language and emotion remains a crucial area for ongoing investigation. Moreover, and according to theories relating positive emotions, cognitive processing and decision-making, this research opens new prospects to further discern the nuanced ways in which positive and negative emotional changes could occur because of meteorological conditions, influencing individuals' overall psychological resilience and social behavior. This further underscores the complexity of environmental factors and their implications in the field in the years ahead.

Author contributions

Conceptualization: JAD; Software/Concept implementation: FR; data acquisition: FR; data analysis: FR and JAD; writing and revision: FR and JAD.

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Disclosure statement

The authors state that they do not have any known competing financial interests or personal ties that may seem to have influenced the work disclosed in this study. All procedures were carried out in conformity with the Helsinki Declaration's ethical norms. The Ethics Committee at the University of Nebrija in Madrid granted the research the required ethical approval. All participants in this study were required to provide informed consent.

Data availability statement

Data is available in the Open Science Framework repository, accessible via the following link: https://doi.org/10.17605/OSF.IO/3KJTU

Supplemental online material.

The following supporting information can be downloaded (i.e., video samples of the VR tasks): https://doi.org/10.17605/OSF.IO/3KJTU

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Tables

Table 1. Descriptive analysis of experimental word stimuli.

	Positive M (SD) [min-max]	Negative M (SD) [min-max]	Neutral M (SD) [min-max]
Valence	7.14 (0.48) [6.53-8.3]	2.78 (0.48) [1.3-3.45]	5.04 (0.35) [4-5.5]
Arousal	6.26 (0.59) [5.4-8.2]	6.34 (0.49) [4.55-6.92]	4.89 (0.47) [4-5.7]
Zipf	3.94 (0.73) [2.38-5.07]	3.99 (0.54) [2.02-5.75]	3.96 (0.12) [3.6-4.1]
Word length	6.12 (0.84) [5-7]	5.99 (0.82) [5-7]	5.94 (0.89) [5-7]
N	100	100	50

Table 2. Descriptive statistics of aggregated ratings and response times across conditions.

Weather Condition	Valence Condition	Valence Rating M (SD) [95% CI]	Response Time in ms M (SD) [95% CI]
Sunny	Positive	6.9 (1.64) [6.82 – 6.92]	1566 (480.28) [1543 - 1588]
Rainy	Positive	6.87 (1.64) [6.79 – 6.95]	1612 (496.54) [1588 – 1636]
Sunny	Negative	3.13 (1.8) [3.04 – 3.21]	1618 (465.05) [1596 - 1640]
Rainy	Negative	3.07 (1.7) [2.99 – 3.15]	1655 (497.29) [1631 - 1679]
Sunny	Neutral	5.19 (1.27) [5.10 – 5.27]	1625 (501.97) [1590 – 1659]
Rainy	Neutral	5.08 (1.24) [4.99 – 5.17]	1641 (540.85) [1604 – 1678]

Figures

Figure 1

Figure 2

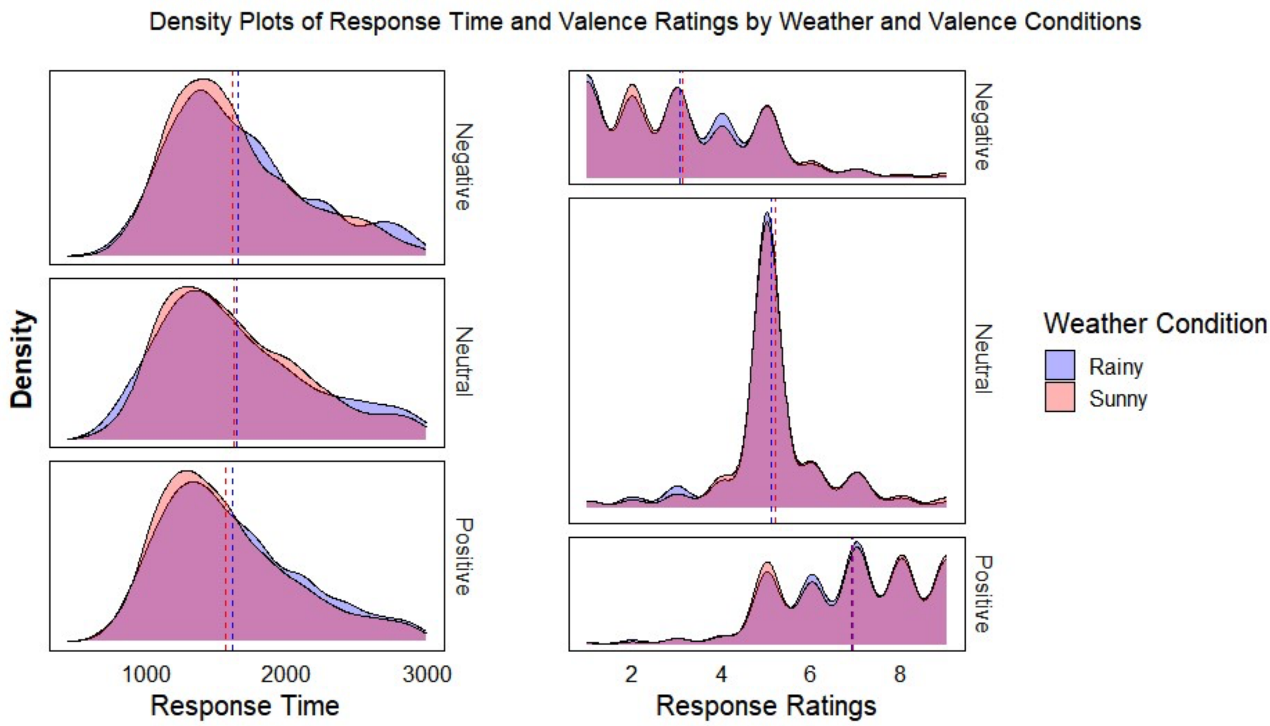
Density Plots of Response Time and Valence Ratings by Weather and Valence Conditions
Density
Negative
Neutral
Positive
1000
2000
3000
Response Time
2
4
6
8
Response Ratings
Weather Condition
Rainy
Sunny

Figure captions

Figure 1. Representation of 3D environment models was employed on the Virtual Reality tasks. The main model is the Spanish rural plaza, accompanied by a presentation billboard and a floating rating console.

Figure 2. Density plots representing participants' reaction times (in milliseconds) and valence ratings across different weather and valence conditions. The left column illustrates the distribution of reaction times under sunny (blue) and rainy (red) conditions for both negative, neutral, and positive words. The right column showcases the distribution of valence ratings, ranging from 1 to 9, under the same weather conditions. Vertical dashed lines within each plot indicate the mean values for each condition.