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Testing the Robustness of Emotional Intensity–Space Associations

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The study design and analysis were not pre-registered.

Abstract

Magnitude information is often associated with space, but whether this spatial organization extends to emotional intensity remains unclear. Across two experiments, we examined spatial associations for task-irrelevant emotional intensity using a gender-judgment task with centrally presented faces. A parity-judgment task administered to the same participants provided an internal benchmark for spatial–numerical associations. In Experiment 1 (N = 66), happy and sad faces varied across four intensity levels. In Experiment 2 (N = 130), participants viewed either happy or fearful faces, allowing intensity-based associations to be examined within separate emotional contexts. Participant-level slope analyses were complemented by trial-level linear mixed-effects models that accounted for variability across participants and face identities. In both experiments, numerical magnitude interacted with the response side in the direction of a reversed spatial–numerical association of response codes effect. In contrast, neither emotional intensity nor its interactions with valence or emotion condition reliably affected left- and right-hand responses. Experiment 1 also provided no evidence for a polarity-based mapping along the sad-to-happy continuum. Emotional intensity nevertheless affected overall response speed, indicating that the intensity manipulation was behaviorally consequential. These findings suggest that task-irrelevant emotional intensity does not invariably recruit horizontal spatial response codes and that previously reported emotional intensity–space associations may depend on the stimuli and task through which intensity is processed.

Keywords: emotional intensity, spatial–numerical associations, SNARC effect, spatial compatibility, facial expressions, polarity correspondence

Spatial–numerical associations (SNAs) refer to systematic relations between numerical information and space. Their best-known behavioral expression is the spatial–numerical association of response codes (SNARC) effect, in which relatively small numbers typically elicit faster left-sided than right-sided responses, whereas the opposite pattern occurs for relatively large numbers (Dehaene et al., 1993). Numerical magnitude can influence spatial responding even when magnitude is irrelevant to the required judgment, as in parity, phoneme-detection, font-detection, and color-judgment tasks (Dehaene et al., 1993; Fias et al., 1996; Notebaert et al., 2006). However, the strength and direction of SNAs vary across task configurations, contextual manipulations, individuals, and cultural and linguistic contexts (Bächtold et al., 1998; Bulut et al., 2026; Cipora et al., 2016; Pitt & Casasanto, 2020; Roth et al., 2024; van Dijck et al., 2009). Even for numerical magnitude, spatial compatibility is therefore sensitive to the conditions under which numerical information is processed.

The possibility that spatial coding extends beyond number has received considerable attention. SNARC-like compatibility effects have been reported for physical size, luminance, loudness, time, facial age, and the typical size of objects (Chang & Cho, 2015; Dalmaso & Vicovaro, 2021; Fumarola et al., 2014; Ishihara et al., 2008; Sellaro et al., 2015; Wühr & Seegelke, 2018). Such findings are broadly compatible with domain-general approaches to magnitude processing. A Theory of Magnitude (ATOM; Walsh, 2003), for example, proposes partially shared processing resources for continuous dimensions such as number, space, time, and quantity. Polarity-correspondence accounts offer a different explanation, according to which compatibility effects can arise when stimulus and response dimensions are coded in terms of corresponding poles, such as low–high and left–right (Proctor & Cho, 2006). Both approaches raise the possibility that graded dimensions other than number may become associated with spatial response codes, although they differ in the mechanisms proposed to underlie such effects.

Emotion has at least two dimensions that may relate to space: valence and intensity. Valence refers to whether an emotional stimulus is relatively negative or positive, whereas intensity refers to the graded strength with which an emotion is expressed. Spatial associations involving valence have been documented across horizontal and vertical dimensions, although their direction and strength depend on factors such as task, response mode, and handedness (Pohl & Miklashevsky, 2025). Recent evidence from an exogenous cueing paradigm further suggests that valence–space mappings can influence spatial attention under particular task conditions (D'Atri et al., 2026). These findings concern the spatial organization of negative and positive information, however, and do not by themselves establish that emotional intensity is represented as a magnitude increasing from left to right.

Holmes and Lourenco (2011) directly investigated emotional intensity using facial expressions. Participants made gender judgments about centrally presented faces whose emotional expressions varied in intensity. Although emotional intensity was irrelevant to the required response, responses were faster to less intense expressions with the left hand and to more intense expressions with the right hand. Because the same participants also displayed the conventional SNARC effect in a number task, the authors proposed that numerical and emotional magnitude might share a common left-to-right spatial organization.

Subsequent findings have made this interpretation less straightforward. Pitt and Casasanto (2018) found no reliable intensity–space association using emotional words and noted that emotional intensity covaried with perceptual features, particularly mouth size, in the facial stimuli used by Holmes and Lourenco (2011). Holmes et al. (2019) replicated the face-based compatibility pattern when mouths were occluded, but participants could infer the size of the hidden mouths, and inferred mouth size accounted for the effect. In a second experiment, however, Holmes et al. obtained an intensity-related spatial effect when

participants explicitly compared the emotional intensity of words. Using happy and sad schematic faces, Prete (2020) found no general left-to-right mapping of either valence or intensity; a low-left/high-right intensity pattern emerged only for happy expressions and only when participants classified emotional valence.

Positive findings have also emerged from comparative-judgment paradigms in which two stimuli are evaluated in relation to one another (Baldassi et al., 2021; Fantoni et al., 2019). These tasks differ from single-stimulus classification because they make relative intensity directly relevant and may involve attentional competition between simultaneously presented expressions. Indeed, subsequent work indicates that performance in emotion-comparison tasks is shaped by low-level attentional dynamics (Dissegna et al., 2023). Compatibility effects across these paradigms therefore show that emotional intensity can interact with spatial processing under some conditions, but they do not establish that a single, task-irrelevant emotional expression automatically activates a stable low-left/high-right mapping.

The central question is consequently not whether emotional intensity can ever be associated with space, but how robustly such an association generalizes across tasks, stimuli, and emotional categories. Relatively few studies have returned to the influential gender-judgment paradigm of Holmes and Lourenco (2011), in which a single face is presented centrally and emotional intensity is irrelevant to the required decision. Testing this paradigm with related but distinct emotional continua can clarify whether its compatibility effect reflects a broadly available emotional magnitude–space association or depends on particular stimulus and task characteristics.

The present study examined spatial coding of task-irrelevant emotional intensity across two experiments. In both experiments, participants completed a parity-judgment task

with numbers and a gender-judgment task with centrally presented emotional faces. Retaining the gender judgment ensured that emotional intensity remained irrelevant to the explicit decision and closely matched the conditions under which the original effect was reported. The number task provided an internal benchmark, allowing emotional intensity–space associations to be evaluated in participants and response settings that also supported spatial coding of numerical magnitude. Across the experiments, we varied the emotional categories and stimulus context to examine whether intensity-based spatial compatibility generalized beyond a single emotional contrast.

Experiment 1

Experiment 1 examined spatial associations for facial expressions that varied in emotional category and intensity. Happy and sad expressions were presented at four morph levels: 0%, 20%, 80%, and 100%. The 0% expressions represented neutral faces at the starting point of each emotional continuum rather than a separate valence category. This design allowed two potentially distinct spatial patterns to be examined. First, responses could vary with emotional intensity irrespective of whether the expression was happy or sad. Second, responses could vary along a signed sad-to-happy polarity continuum.

For the number task, we expected a systematic association between numerical magnitude and response side but made no directional prediction. Studies with Turkish participants have produced conventional, null, and reversed spatial–numerical associations across different tasks and samples (Bulut et al., 2023, 2024, 2026; Dural et al., 2025). The direction of the numerical association was therefore treated as an empirical outcome. For the face task, an emotional intensity–space association would be indicated by an interaction between intensity and response side. A polarity-based association would be indicated by

systematic variation in response-side differences along the sad-to-happy continuum. No directional prediction was specified for either association.

Method

Participants

A priori power analysis was conducted using G*Power (Version 3.1.9.7; Faul et al., 2009) to determine the required sample size. Effect sizes from Holmes and Lourenco (2011, Experiment 2) were used as a reference, with $d = .46$ for the number task and $d = .32$ for the face task. Based on the average effect size ($d = .39$), a sample size of 61 was estimated to provide 85% power to detect a group level spatial compatibility effect using a two-tailed one-sample *t*-test ($\alpha = .05$). Based on this analysis, 66 participants were recruited to allow for potential data loss and to ensure that the target sample size was retained (42 women; *M*age = 20.44 years, *SD* = 3.60, range = 18–46 years). All participants were native Turkish speakers with normal or corrected-to-normal vision and provided written informed consent. Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971); eight participants were classified as left-handed. The study protocol was approved by the local ethics committee and was conducted in accordance with the Declaration of Helsinki (approval details withheld for blind review).

Stimuli and Apparatus

A parity judgment task was employed as the number task to assess SNARC performance. Participants judged whether centrally presented Arabic digits (1–9, excluding 5) were odd or even. The digits were displayed in black on a white background using Courier New font (size 55). For the face task, stimuli were selected from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). Ten male and ten female models were selected, with equal numbers of male and female faces assigned to the happy-

neutral or a sad-neutral continua. Thus, each emotional continuum comprised five male and five female models. For each model, four emotional intensity levels (0%, 20%, 80%, and 100%) were created using Abrosoft FantaMorph Deluxe 5 (http://www.fantamorph.com/index.html; see Figure S1 in the Supplementary Material). This procedure yielded a total of 80 unique face stimuli. All face images were presented in grayscale, centered on a white background, and cropped to remove non-diagnostic features such as hair, neck, and ears to minimize gender-related visual cues.

Stimuli for both tasks were displayed on a 20" LCD monitor (1920 × 1080 resolution; 60 Hz refresh rate) using SuperLab 6.0 software (Cedrus Corp.). Responses were recorded using the same software via a standard Turkish QWERTY keyboard. Participants pressed the "A" and "İ" keys, corresponding to the left-most and right-most letter keys located on the same middle horizontal row of the keyboard, for left- and right-hand responses, respectively. This setup ensured that the response keys were horizontally aligned and spatially separated, corresponding to the left and right hands (see Figure S2 in the Supplementary Material).

Procedure

Each participant completed both the number task and the face task in a counterbalanced order. In the number task, participants performed a parity judgment, indicating whether a displayed digit was odd or even. In the face task, they completed a gender judgment by classifying each face as male or female. Responses in both tasks were made using the "A" or "İ" keys, operated with the left and right index fingers, respectively.

Each task comprised two blocks with reversed response mappings, separated by a 30-s rest period. Mapping order was counterbalanced across participants. Each block of the number task began with eight practice trials followed by 80 test trials, yielding 160 test trials in total. Each digit appeared 10 times per block in random order. Similarly, each block of the

face task included eight practice trials followed by 80 test trials. Each of the 80 face stimuli was presented once per block, yielding 160 test trials in total.

During practice trials, participants received feedback on errors and responses slower than 1500ms. Each trial began with a 300-ms fixation cross, followed by the stimulus, which remained on screen until a response was made. A blank screen appeared for 500ms before the next trial began. No feedback was provided during the test phase. Participants were instructed to respond as quickly and accurately as possible throughout both tasks.

Data Preparation

Practice trials were excluded before data processing. Among the test trials, incorrect responses accounted for 3.7% of the number task data and 5.4% of the face task data and were excluded from the RT analyses. Trials with RTs shorter than 200 ms were subsequently removed. Finally, RTs falling more than 2.5 standard deviations from each participant's task-specific mean were excluded, with the means and standard deviations calculated after removing incorrect responses and responses shorter than 200 ms. Participants for whom fewer than 75% of the trials remained valid in either task were excluded from both task datasets. Following these procedures, the overall trial loss was 6.7% in the number task and 8.4% in the face task.

Data Analysis

We first conducted conventional participant-level slope analyses following the procedure introduced by Fias et al. (1996). For each participant, mean response times (RTs) were calculated separately for left- and right-hand responses at each predictor level. Difference scores were computed by subtracting the mean RT for left-hand responses from the mean RT for right-hand responses. Individual unstandardized regression slopes were then estimated and tested against zero using two-tailed one-sample *t*-tests.

For the number task, difference scores were regressed on numerical magnitude. A negative slope reflected the conventional SNARC effect—that is, relatively faster left-hand responses to smaller numbers and faster right-hand responses to larger numbers—whereas a positive slope reflected the reverse pattern. For the face task, two complementary slopes were calculated. The polarity slope was based on a signed emotion continuum, with sad expressions assigned negative values, happy expressions assigned positive values, and 0% intensity expressions positioned at zero. A negative polarity slope indicated relatively faster left-hand responses to sad expressions and faster right-hand responses to happy expressions. The unsigned intensity slope was based on absolute emotional intensity (0%, 20%, 80%, and 100%), collapsing across happy and sad expressions. A negative intensity slope indicated relatively faster left-hand responses to lower-intensity expressions and faster right-hand responses to higher-intensity expressions.

Bayesian one-sample *t*-tests were conducted alongside the frequentist tests for all three slope measures. Bayes factors (BF_{10}) were calculated using the default Cauchy prior with an *r*-scale of 0.707. Following Dienes (2021), BF_{10} values greater than 3 and 10 were interpreted as moderate and strong evidence for the alternative hypothesis, respectively. Values below 1/3 and 1/10 were interpreted as moderate and strong evidence for the null hypothesis, respectively, whereas values between 1/3 and 3 were considered inconclusive. Trial-level RTs were additionally analyzed using linear mixed-effects models fitted in R with the lme4 and lmerTest packages. Models were estimated using restricted maximum likelihood, and inferential tests for fixed effects used Satterthwaite-approximated degrees of freedom. Continuous predictors were centered, and binary predictors were effect-coded.

For the number task, numerical magnitude was centered around the scale midpoint, response side was coded as −0.5 for left and 0.5 for right, and parity was coded as −0.5 for odd and 0.5 for even. The fixed-effects structure included numerical magnitude, response

side, parity, the interaction between numerical magnitude and response side, and the interaction between parity and response side. The magnitude-by-response-side interaction constituted the trial-level test of the SNARC effect. Parity and its interaction with the response side were included as control terms because parity was the task-relevant classification dimension. The random-effects structure included participant-specific intercepts and uncorrelated slopes for magnitude, response side, and their interaction.

For the face task, valence was effect-coded as −0.5 for happy and 0.5 for sad. Intensity was rescaled to range from 0 to 1 and centered around its midpoint, resulting in values of −0.5, −0.3, 0.3, and 0.5 for the 0%, 20%, 80%, and 100% levels, respectively. Response side was coded as −0.5 for left and 0.5 for right. The fixed-effects structure included the full interaction among valence, intensity, and response side. The intensity-by-response-side interaction tested whether the spatial association varied as a function of emotional intensity, whereas the three-way interaction tested whether this relationship differed between happy and sad expressions. The final random-effects structure included random intercepts for participants and face identities, in which each individual model constituted a distinct face identity across morph levels, together with an uncorrelated participant-specific slope for response side. More complex theoretically motivated random-slope structures were initially evaluated but produced singular fits and were therefore simplified by removing unsupported variance components. The final models converged without warnings and were non-singular. Significant interactions were followed up using estimated marginal trends computed with the emmeans package.

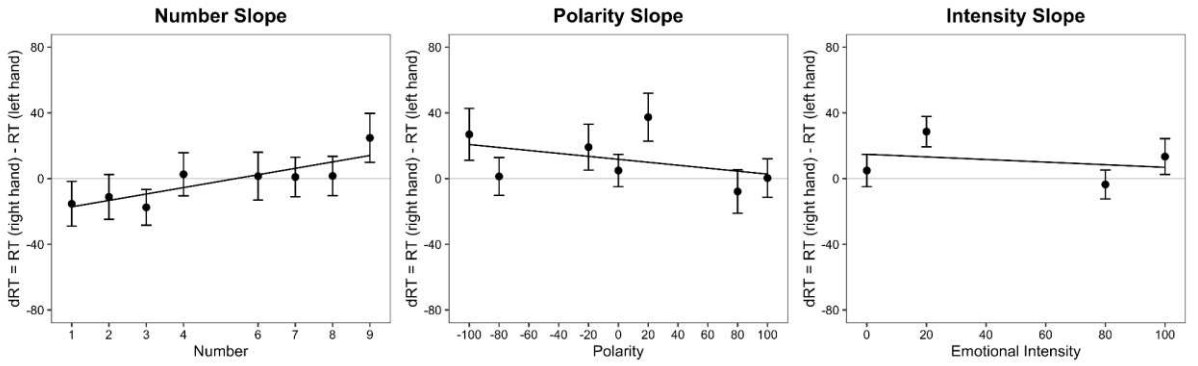
Results

Overall accuracy was 96.3% in the number task and 94.6% in the face task. Mean RT was 617.81 ms (*SD* = 199.77) in the number task and 731.98 ms (*SD* = 303.83) in the face task.

The participant-level number slopes were significantly positive, $M = 3.91$, $SD = 11.76$, $t(65) = 2.70$, $p = .009$, $d = 0.33$, $BF_{10} = 3.75$. This result provided moderate evidence for a reversed SNARC effect. In the face task, the mean polarity slope did not differ significantly from zero, $M = -0.09$, $SD = 0.55$, $t(65) = -1.34$, $p = .185$, $BF_{10} = 0.32$. The mean intensity slope likewise did not differ from zero, $M = -0.08$, $SD = 0.86$, $t(65) = -0.75$, $p = .456$, $BF_{10} = 0.18$. The Bayes factors provided moderate evidence for the null hypothesis for both face-task slopes.

Figure 1

Linear regression plots illustrating the number slope for the number task, and the polarity and intensity slopes for the face task. Error bars indicate ±1 SEM.



The trial-level model for the number task showed a significant numerical magnitude × response side interaction, $b = 3.92$, $SE = 1.37$, $t(62.88) = 2.85$, $p = .006$. Estimated trends indicated that numerical magnitude was not reliably associated with RT for left-hand responses, $b = 0.23$, $SE = 0.97$, 95% CI [−1.66, 2.12], whereas RT increased with numerical

magnitude for right-hand responses, $b = 4.15$, $SE = 0.97$, 95% CI [2.25, 6.04]. The difference between these trends was significant, $b = -3.92$, $SE = 1.37$, $z = -2.85$, $p = .004$. This pattern reflected a relative right-hand advantage for smaller numbers and a relative left-hand advantage for larger numbers, consistent with a reversed SNARC effect.

The model also showed main effects of numerical magnitude, $b = 2.19$, $SE = 0.68$, $t(64.17) = 3.21$, $p = .002$, and parity, $b = -8.41$, $SE = 3.44$, $t(9624.24) = -2.45$, $p = .014$. Responses to even numbers were approximately 8 ms faster than responses to odd numbers. Neither the main effect of response side, $b = -1.70$, $SE = 4.10$, $t(65.01) = -0.42$, $p = .679$, nor the parity x response side interaction, $b = -0.97$, $SE = 6.87$, $t(9609.29) = -0.14$, $p = .887$, was significant.

The trial-level model for the face task provided no evidence that emotional intensity was differentially associated with the two response sides. Neither the intensity x response side interaction, $b = -4.95$, $SE = 12.21$, $t(9520.29) = -0.41$, $p = .685$, nor the valence x intensity x response side interaction, $b = 20.39$, $SE = 24.43$, $t(9519.02) = 0.83$, $p = .404$, was significant. The valence x response side interaction was also not significant, $b = 9.36$, $SE = 10.09$, $t(9525.73) = 0.93$, $p = .353$.

Independent of response side, valence and intensity interacted, $b = 58.43$, $SE = 12.22$, $t(9518.17) = 4.78$, $p < .001$. RT decreased with increasing intensity for happy expressions, $b = -43.70$, $SE = 8.51$, 95% CI [−60.40, −27.00]. For sad expressions, the estimated intensity trend was positive, but its confidence interval included zero, $b = 14.70$, $SE = 8.77$, 95% CI [−2.46, 31.90]. Thus, intensity affected overall response speed differently for happy and sad expressions, but this effect did not constitute a spatial association.

The main effect of valence was not significant, $b = 30.28$, $SE = 28.41$, $t(17.84) = 1.07$, $p = .301$. The main effect of response side also did not reach significance, $b = 11.60$, $SE =$

6.24, $t(63.06) = 1.86$, $p = .068$. The average effect of intensity was significant, $b = -14.50$, $SE = 6.11$, $t(9520.72) = -2.37$, $p = .018$, but was qualified by the valence x intensity interaction. Both models converged without warnings and were non-singular.

Discussion

Experiment 1 examined whether task-irrelevant emotional information in facial expressions was associated with horizontal response codes. The number task produced a reversed SNARC effect, with a relative right-hand advantage for smaller numbers and a relative left-hand advantage for larger numbers. In contrast, the face task provided no evidence for either a polarity-based mapping along the sad-to-happy continuum or an intensity-based spatial mapping. This conclusion converged across participant-level slopes and trial-level mixed-effects models. The Bayesian tests applied to the participant-level slopes provided moderate evidence for the absence of both face-task mappings, and none of the mixed-effects interactions involving emotional intensity or valence and response side was significant.

The numerical result provided an internal benchmark showing that the response arrangement was capable of revealing a systematic magnitude–space association. The absence of a corresponding face-task effect is therefore unlikely to reflect a general insensitivity of the response setup. Emotional intensity nevertheless affected overall response speed: RT decreased with increasing intensity for happy expressions, whereas the estimated intensity trend for sad expressions was not reliably different from zero. Participants were therefore sensitive to variation in the emotional expressions, but this variation did not differentially affect left- and right-hand responses.

Because happy and sad expressions occurred within the same face task, however, intensity was processed in a context that also contained a salient contrast between emotional

categories. Experiment 2 examined whether an emotional intensity–space association would emerge when participants encountered only one emotional category and intensity varied within that category.

Experiment 2

Experiment 2 examined emotional intensity within separate emotional continua. Participants were assigned to either a happy or a fear condition, and faces varied across the same four morph levels within each condition. By removing the direct happy–sad contrast from the task, this design allowed intensity-based spatial compatibility to be examined separately within positive and negative emotional contexts.

Fear was selected because it provided a negative emotional context that differed from the sadness continuum used in Experiment 1. Fear expressions are generally more arousing and motivationally salient than sad expressions, making them useful for examining whether intensity-based spatial compatibility generalizes across substantially different emotional categories. The happy and fearful continua were not assumed to be equivalent on all affective or perceptual dimensions. Rather, they provided two distinct contexts in which graded intensity could be examined. Perceived intensity differences among the morph levels were independently validated for both continua.

As in Experiment 1, we expected a systematic association between numerical magnitude and response side but made no directional prediction. If spatial coding of emotional intensity is generalized across emotional categories, intensity should interact with the response side in the face task. An intensity x response side x emotion condition interaction would indicate that the association differed between happy and fear expressions. No directional predictions were specified.

Method

Participants

A total of 138 participants were recruited. Eight participants were excluded because they did not follow the task instructions (n = 3) or retained fewer than 75% valid trials in at least one task (n = 5). The final sample comprised 130 participants, with 65 participants in the happy condition (40 women; *M*age = 21.85 years, *SD* = 3.51, range = 18–37 years) and 65 participants in the fear condition (38 women; *M*age = 24.22 years, *SD* = 6.65, range = 18–55 years). All participants were native Turkish speakers with normal or corrected-to-normal vision. Ten participants were classified as left-handed using the Edinburgh Handedness Inventory (Oldfield, 1971). All participants provided written informed consent.

Stimuli

The stimuli used in the number task and in the happy face task were identical to those employed in Experiment 1. For the current experiment, only the fear expressions were newly created. Using the same set of face models at 0% intensity (i.e., neutral faces), fear stimuli were generated at 20%, 80%, and 100% emotional intensity levels (see Figure S1 in the Supplementary Material), yielding 40 distinct facial expressions.

Procedure

Emotion type (happy vs. fear) was manipulated as a between-subjects factor. Participants were randomly assigned to one of two groups: one group completed the number task and the happy face task, while the other completed the number task and the fear face task. Task order was counterbalanced across participants. In both versions of the face task, each emotional face stimulus was presented twice, resulting in 80 test trials per block, yielding a total of 160 test trials (40 faces x 2 times x 2 blocks), matching the number of face-

task trials in Experiment 1. Aside from these modifications to the emotion manipulation and stimulus presentation, all other aspects of the experimental procedure and apparatus were identical to those used in Experiment 1.

Ratings of Face Stimuli

To assess whether the intensity levels created using the Abrosoft FantaMorph Deluxe 5 produced distinguishable levels of perceived emotional intensity, the mean intensity ratings were collected from independent groups of participants. A group of participants ($N = 47$) rated the emotional intensity of each happy face stimulus on a 10-point scale (1 = neutral, 10 = very happy). The mean ratings were as follows: 2.16 (neutral), 2.79 (20% happy), 6.24 (80% happy), and 7.10 (100% happy). A separate group of participants ($N = 44$) rated the fear expressions on a corresponding 10-point scale (1 = neutral, 10 = very fearful). The mean fear ratings were 2.13 (neutral), 2.45 (20% fear), 6.11 (80% fear), and 6.58 (100% fear).

Two separate one-way repeated-measures ANOVAs were conducted to test whether mean intensity ratings significantly differed across the four intensity levels for happy and fear expressions, respectively. The repeated-measures ANOVA for the ratings of happy expressions revealed a significant main effect of intensity level, $F(1.38, 63.40) = 403.89$, $p < .001$, $\eta_p^2 = .90$. All pairwise comparisons between the four intensity levels (0%, 20%, 80%, and 100%) were statistically significant ($p_s < .01$), indicating a systematic increase in perceived intensity across levels. Similarly, for fear expressions, the analysis revealed a significant main effect of intensity level, $F(1.30, 55.72) = 253.89$, $p < .001$, $\eta_p^2 = .86$. Again, all pairwise comparisons were significant ($p_s < .05$), showing that fear intensity ratings also increased systematically from 0% to 100%. These results confirmed that the intensity manipulation was effective, perceived emotional intensity increased systematically across the four morph levels for both happy and fear expressions.

Data Preparation

Practice trials were excluded before data processing. For the test trials, incorrect responses were removed, accounting for 3.8% and 4.6% of the number task data in the happy and fear conditions, respectively, and 3.2% and 4.4% of the face task data. Trials with RTs shorter than 200 ms were then excluded. Finally, RTs falling more than 2.5 standard deviations from each participant's task-specific mean were removed, with the means and standard deviations calculated after excluding incorrect responses and responses shorter than 200 ms. Participants for whom fewer than 75% of the trials remained valid in either task were excluded from both task datasets. Following these procedures, the overall trial loss was 6.5% and 7.2% in the Number Task and 6.2% and 7.4% in the face task for the happy and fear conditions, respectively.

Data Analysis

Participant-level slope analyses followed the procedure used in Experiment 1. For each participant, mean RTs were calculated separately for left- and right-hand responses at each predictor level, and difference scores were computed as mean right-hand RT minus mean left-hand RT. Individual unstandardized regression slopes were then estimated and tested against zero using two-tailed one-sample t-tests.

For the number task, difference scores were regressed on numerical magnitude. Negative slopes indicated the conventional SNARC pattern, with relatively faster left-hand responses to smaller numbers and faster right-hand responses to larger numbers, whereas positive slopes indicated the reverse pattern. These analyses were conducted separately for participants in the happy and fear conditions.

For the face task, difference scores were regressed on the independently obtained mean intensity ratings for the four morph levels within each emotion condition. The ratings

were 2.16, 2.79, 6.24, and 7.10 for the happy expressions and 2.13, 2.45, 6.11, and 6.58 for the fear expressions. Negative slopes indicated relatively faster left-hand responses to lower-intensity expressions and faster right-hand responses to higher-intensity expressions, whereas positive slopes indicated the reverse pattern. As a robustness check, the face task slopes were also calculated using the predefined morph levels of 0%, 20%, 80%, and 100%; these results are reported in the Supplementary Material.

Bayesian one-sample t-tests were conducted alongside the frequentist tests for all participant-level slope measures. Bayes factors (BF_{10}) were calculated using the default Cauchy prior with an r-scale of 0.707. Following Dienes (2021), BF_{10} values greater than 3 and 10 were interpreted as moderate and strong evidence for the alternative hypothesis, respectively. Values below 1/3 and 1/10 were interpreted as moderate and strong evidence for the null hypothesis, respectively, whereas values between 1/3 and 3 were considered inconclusive.

Trial-level RTs were additionally analyzed using linear mixed-effects models fitted in R with the lme4 and lmerTest packages. Models were estimated using restricted maximum likelihood, and tests of fixed effects used Satterthwaite-approximated degrees of freedom. Continuous predictors were centered, and binary predictors were effect-coded.

For the number task, numerical magnitude was centered around the scale midpoint, response side was coded as −0.5 for left and 0.5 for right, parity was coded as −0.5 for odd and 0.5 for even, and emotion condition was coded as −0.5 for happy and 0.5 for fear. The fixed-effects structure included the full interaction among numerical magnitude, response side, and emotion condition, together with the interaction between parity and response side. The magnitude x response side interaction tested the overall SNARC effect, whereas the magnitude x response side x emotion condition interaction tested whether the SNARC effect

differed between the happy and fear conditions. The initial random-effects structure included participant-specific intercepts and uncorrelated slopes for numerical magnitude, response side, and the magnitude x response side interaction. Because the variance of the participant-specific magnitude slope was estimated as zero, producing a singular fit, this unsupported component was removed. The final random-effects structure therefore included participant-specific intercepts and uncorrelated slopes for response side and the magnitude × response side interaction.

For the face task, morph intensity was rescaled to range from 0 to 1 and centered around its midpoint, resulting in values of −0.5, −0.3, 0.3, and 0.5 for the 0%, 20%, 80%, and 100% levels, respectively. Response side and emotion condition were effect-coded as described above. The fixed-effects structure included the full interaction among intensity, response side, and emotion condition. The intensity x response side interaction tested the overall association between emotional intensity and response side, whereas the intensity x response side x emotion condition interaction tested whether this association differed between happy and fear expressions. The random-effects structure included random intercepts for participants and face identities and an uncorrelated participant-specific slope for response side.

Model convergence and singularity were evaluated for both models. Significant interactions were followed up using estimated marginal trends computed with the emmeans package.

Results

In the happy condition, accuracy was 96.2% in the number task and 96.8% in the face task. Mean RT was 598.27 ms (*SD* = 182.84) in the number task and 632.82 ms (*SD* = 176.05) in the face task. In the fear condition, accuracy was 95.4% in the number task and

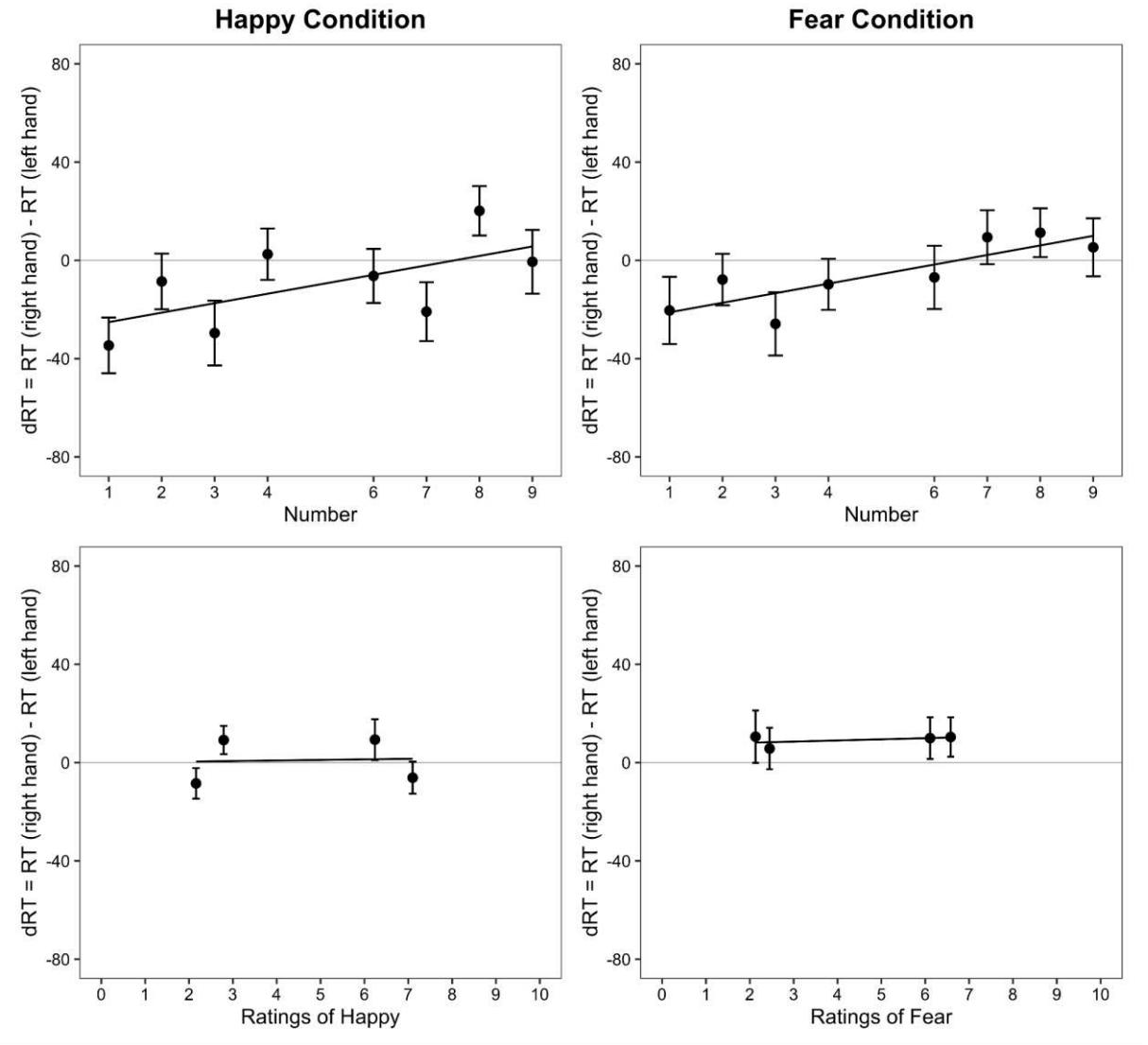
95.6% in the face task. Mean RT was 599.06 ms (*SD* = 188.71) in the number task and 703.33 ms (*SD* = 252.80) in the face task.

In the participant-level analyses, the number slopes were significantly positive in both conditions. In the happy condition, $M = 3.85$, $SD = 12.21$, $t(64) = 2.54$, $p = .014$, $d = 0.32$, $BF_{10} = 2.63$. Although the frequentist test indicated a reversed SNARC effect, the corresponding Bayesian evidence was inconclusive. In the fear condition, $M = 3.89$, $SD = 11.06$, $t(64) = 2.84$, $p = .006$, $d = 0.35$, $BF_{10} = 5.21$, providing moderate evidence for a reversed SNARC effect.

The face-task intensity slopes did not differ from zero in either condition. In the happy condition, $M = 0.23$, $SD = 10.92$, $t(64) = 0.17$, $p = .866$, $BF_{10} = 0.14$. In the fear condition, $M = 0.46$, $SD = 18.95$, $t(64) = 0.20$, $p = .842$, $BF_{10} = 0.14$. Both Bayes factors provided moderate evidence for the null hypothesis.

Figure 2

Linear regression plots illustrating the number slope for the number task (top row) and the intensity slope for the face task (bottom row), separately for the happy and fear conditions. Error bars indicate ±1 SEM.



The trial-level number-task model showed a significant numerical magnitude × response side interaction, $b = 3.87$, $SE = 1.00$, $t(128.40) = 3.85$, $p < .001$, indicating an overall reversed SNARC effect. Crucially, the numerical magnitude x response side x emotion condition interaction was not significant, $b = -0.07$, $SE = 2.01$, $t(128.39) = -0.03$, $p = .974$. The numerical magnitude x emotion condition interaction, $b = 0.69$, $SE = 0.84$, $t(19020.29) = 0.82$, $p = .413$, and response side x emotion condition interaction, $b = 3.43$, $SE = 6.21$, $t(127.35) = 0.55$, $p = .582$, were also not significant. Thus, neither the numerical magnitude effect nor its spatial compatibility differed between the happy and fear conditions.

Follow-up trends showed the same reversed response-side pattern in both conditions. In the happy condition, the numerical magnitude trend was not reliably different from zero for left-hand responses, $b = 0.56$, $SE = 0.93$, 95% CI [−1.27, 2.38], but was positive for right-hand responses, $b = 4.46$, $SE = 0.93$, 95% CI [2.65, 6.27]. The difference between these trends was significant, $b = -3.90$, $SE = 1.42$, $z = -2.75$, $p = .006$. In the fear condition, the trend was not reliably different from zero for left-hand responses, $b = 1.28$, $SE = 0.93$, 95% CI [−0.54, 3.10], but was positive for right-hand responses, $b = 5.12$, $SE = 0.93$, 95% CI [3.30, 6.93]. Their difference was also significant, $b = -3.84$, $SE = 1.42$, $z = -2.70$, $p = .007$.

The number-task model additionally showed main effects of numerical magnitude, $b = 2.85$, $SE = 0.42$, $t(19020.30) = 6.76$, $p < .001$; response side, $b = -7.78$, $SE = 3.11$, $t(127.35) = -2.51$, $p = .013$; and parity, $b = -16.29$, $SE = 2.30$, $t(19015.49) = -7.07$, $p < .001$. The parity x response side interaction was also significant, $b = 13.00$, $SE = 4.61$, $t(19012.28) = 2.82$, $p = .005$. Emotion condition had no main effect on number-task RT, $b = -0.39$, $SE = 16.46$, $t(127.96) = -0.02$, $p = .981$.

The trial-level face-task model provided no evidence for an emotional intensity–space association. The intensity x response side interaction was not significant, $b = 2.69$, $SE = 6.41$, $t(19119.33) = 0.42$, $p = .675$. The intensity x response side x emotion condition interaction was also not significant, $b = 0.71$, $SE = 12.82$, $t(19119.34) = 0.06$, $p = .956$, indicating that the spatial pattern did not differ between happy and fear expressions. The response side x emotion condition interaction was likewise not significant, $b = 7.90$, $SE = 7.08$, $t(126.72) = 1.12$, $p = .266$.

Independent of the response side, RT decreased slightly as emotional intensity increased, $b = -8.58$, $SE = 3.21$, $t(19118.26) = -2.68$, $p = .007$. The intensity x emotion condition interaction was not significant, $b = 9.74$, $SE = 6.41$, $t(19118.24) = 1.52$, $p = .129$.

RT was generally slower in the fear condition than in the happy condition, $b = 71.05$, $SE = 19.29$, $t(127.99) = 3.68$, $p < .001$. The main effect of response side was not significant, $b = 5.24$, $SE = 3.54$, $t(126.72) = 1.48$, $p = .141$. Both final models converged without warnings and were non-singular.

Discussion

Experiment 2 examined emotional intensity–space associations within separate emotional continua. The number task again produced a reversed SNARC effect. Importantly, the numerical magnitude x response side x emotion condition interaction was not significant, and follow-up trends revealed comparable reversed patterns in the happy and fear conditions. The participant-level analyses were directionally consistent, although the Bayesian evidence was inconclusive in the happy condition and moderately supported the reversed association in the fear condition.

The face task again provided no evidence for an emotional intensity–space association. Participant-level intensity slopes did not differ from zero in either condition, and both Bayesian tests provided moderate evidence for the null hypothesis. Correspondingly, the mixed-effects model showed neither an intensity x response side interaction nor an intensity x response side x emotion condition interaction. Emotional intensity therefore did not differentially affect left- and right-hand responses, and this pattern did not vary reliably between happy and fear expressions.

Separating the emotional categories addressed the possibility that the direct happy–sad contrast in Experiment 1 had obscured intensity-based spatial coding. The persistence of the null spatial result suggests that the Experiment 1 findings cannot readily be attributed to the simultaneous variation of valence and intensity. Although increasing intensity modestly reduced overall RT and responses were slower in the fear condition, neither effect involved

response side. Across distinct positive and negative emotional contexts, task-irrelevant emotional intensity therefore failed to produce a reliable horizontal mapping despite the spatial coding of numerical magnitude under the same response arrangement.

General Discussion

The present study examined whether task-irrelevant emotional intensity recruits horizontal spatial response codes under conditions modeled closely on the gender-judgment paradigm of Holmes and Lourenco (2011). Across two experiments, the number task consistently produced a reversed SNARC effect, whereas the face task provided no reliable evidence that emotional intensity was associated with the response side. Experiment 1 also showed no polarity-based mapping along the sad-to-happy continuum. In Experiment 2, examining happy and fear expressions in separate participant groups did not change the intensity–space result. These conclusions converged across participant-level slope analyses and trial-level mixed-effects models that accounted for variability across participants and face identities.

The reversed SNARC effect observed in both experiments fits within the broader variability reported in Turkish samples, which have shown regular (Bulut et al., 2024), null (Bulut et al., 2023; Dural et al., 2025), and reversed associations (Bulut et al., 2026). This mixed evidence suggests that spatial–numerical mappings may not be expressed with a single stable direction in this population. Broader culturally shaped directional experiences may contribute to this variability, alongside differences in task demands and experimental context. Particularly relevant is the recent high-powered laboratory study by Bulut et al. (2026), which found a weak reversed SNARC effect in a standard parity task but a left-to-right association under a different task configuration. The present findings converge with its parity-task result and replicate the reversed association across two independent samples.

The contrast between the number and face tasks is central to the present findings. Participants showed systematic compatibility between numerical magnitude and response side using the same lateralized response arrangement in which emotional intensity produced no spatial effect. The face-task null results are therefore unlikely to reflect a general inability of these samples to associate magnitude with horizontal responses or a response setup that was insensitive to spatial compatibility. Instead, the results show that a spatial mapping observed for one graded dimension does not necessarily extend to another. Emotional intensity affected overall response speed, confirming that the intensity manipulation was behaviorally consequential, but these effects did not differ between left- and right-hand responses.

The absence of an emotional intensity–space association qualifies rather than overturns the findings of Holmes and Lourenco (2011). Their study provided influential evidence that less intense facial expressions were associated with the left and more intense expressions with the right, even when emotion was irrelevant to the gender judgment. Subsequent work has shown that this pattern is not straightforward. Pitt and Casasanto (2018) demonstrated that emotional intensity covaried with mouth size in the original stimuli and found no intensity mapping with emotional words. Holmes et al. (2019) again obtained a left-to-right association for faces with occluded mouths, but the effect could be explained by inferred mouth size. In contrast, their second experiment found an intensity-related spatial effect when participants explicitly compared emotional words. The available evidence therefore suggests that emotional intensity–space associations may depend on both the stimulus set and the extent to which the task makes relative intensity salient.

The present study tested this association across happy, sad, and fear expressions. These categories differ in valence, arousal, motivational relevance, attentional salience, and perceptual configuration. The absence of an emotional intensity–space association across

these contexts suggests that the original face-based effect does not generalize automatically to every emotional category that varies in strength. At the same time, the findings do not establish that emotional intensity is never spatialized. They identify a boundary condition: with single, centrally presented faces and a task-irrelevant gender judgment, graded emotional intensity did not reliably activate horizontal response codes in the present samples.

The role of task demands may help reconcile the current results with positive findings from comparative judgments. Explicit comparison requires participants to evaluate stimuli relative to one another and makes emotional intensity central to the decision (Baldassi et al., 2021; Fantoni et al., 2019; Holmes et al., 2019, Experiment 2). Performance in these paradigms also appears to reflect attentional competition between the stimuli and the temporal dynamics of emotion comparison (Dissegna et al., 2023). Such tasks may therefore support spatial compatibility without implying that emotional intensity automatically activates the same spatial code when it is irrelevant to a single-stimulus judgment. This distinction is also consistent with evidence that valence–space associations vary across tasks and measures (D'Atri et al., 2026; Pohl & Miklashevsky, 2025).

Perceptual characteristics of the expressions may also contribute to variability across studies. Changes in morph intensity necessarily alter visible facial features, but the diagnostic features and their spatial extent differ across happiness, sadness, fear, and anger. The relevant compatibility effect could therefore reflect emotional intensity, perceptual magnitude, or shared variation between the two. The current study cannot isolate these components, but the failure to obtain the same spatial pattern across several emotional continua reinforces the need to distinguish emotional and perceptual contributions before interpreting a compatibility effect as evidence for an emotional magnitude line.

Cultural experience provides another possible source of variation. Directional numerical associations in Turkish samples have not consistently followed one pattern, and the same may be true of other conceptual dimensions. The presence of a reversed numerical association alongside null emotional associations is noteworthy because it shows that horizontal magnitude–response compatibility was available in these samples. It does not, however, demonstrate that culture affects numerical and emotional mappings through the same mechanisms. Cross-cultural studies using matched stimuli and procedures would be needed to determine whether variation in emotional intensity–space associations reflects culturally shaped directional experience, the selected emotional categories, or task-specific demands.

The findings also constrain broad interpretations of domain-general magnitude processing. ATOM proposes partially shared processing of dimensions such as number, space, time, and quantity (Walsh, 2003), but does not require every graded dimension to produce an equivalent directional response pattern under every task condition. The present dissociation between number and emotional intensity indicates that a graded continuum alone is insufficient to produce horizontal compatibility. Polarity correspondence provides a complementary perspective: numerical magnitude may establish relatively stable small–large poles, whereas task-irrelevant intensity embedded in complex facial expressions may not establish equally stable low–high response codes. Moreover, compatibility effects obtained in binary classification tasks do not uniquely demonstrate spatial representation because they may also arise from correspondence between stimulus and response polarities (Holmes et al., 2019; Proctor & Cho, 2006). The present null effects therefore argue against inferring a robust emotional magnitude line solely from the graded nature of emotional intensity.

The design also defines several questions for future research. Varying emotional categories across experiments allowed the generality of the null intensity–space result to be examined beyond a single emotional contrast, but did not provide a fully crossed comparison of multiple emotions within the same participants. Future studies could compare a wider range of emotional categories within a common design to determine whether particular expressions are more likely to support spatial coding. Independently measuring or controlling features such as mouth and eye configuration would help distinguish emotional intensity from perceptual magnitude. The gender-judgment task was a deliberate feature of the present study because it kept emotional intensity irrelevant and provided a test of spontaneous compatibility. Complementary studies could administer task-irrelevant gender judgments, explicit intensity classifications, and comparative judgments using the same stimuli and participants. Matched cross-cultural implementations would further clarify the relative contributions of emotional category, task demands, perceptual properties, and directional experience.

In conclusion, numerical magnitude was reliably associated with response side across both experiments, although in the reversed direction, whereas emotional intensity was not. The absence of an emotional mapping across happy, sad, and fear contexts, together with evidence that participants nevertheless processed the intensity manipulation, indicates that task-irrelevant emotional intensity does not invariably recruit horizontal spatial response codes. Emotional intensity–space associations should therefore be evaluated in relation to the specific stimuli and tasks through which emotional intensity is processed rather than treated as a stable counterpart of spatial–numerical associations.

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