Age-related vertical space-valence metaphors

Siqi Zhu (Graduate School of Human-Environment Studies, Kyushu University, knmoonless@gmail.com)
Kyoshiro Sasaki (Faculty of Informatics, Kansai University, kyoshiro0920@gmail.com, Japan)
Yue Jiang (Yunnan Provincial Institute of Ethnic Studies, Yunnan Minzu University, 18487155194@163.com, Japan)
Kun Qian (Institute for Asian and Oceanian Studies, Kyushu University, kkcs2000@icloud.com, Japan)
Yuki Yamada (Faculty of Arts and Science, Kyushu University, yamadayuk@gmail.com, Japan)

加齢に関連した垂直空間感情メタファー

朱 思斉（九州大学 大学院人間環境学府）
佐々木 恭志郎（関西大学 総合情報学部）
姜 月（雲南民族大学 民族学研究所）
錢 琨（九州大学 アジア・オセアニア研究教育機構）
山田 祐樹（九州大学 基幹教育院）

要約

垂直空間感情メタファー（たとえば「上」はポジティブな感情と、「下」はネガティブな感情と結びつく）は、身体化認知の基本的な例の一つとされている。しかし、これらの連合が生涯を通じてどのように形成され、変化していくのかについての研究はほとんど行われていない。本研究では、クラウドソーシングサービスを用いたオンライン実験を通じて、加齢と垂直空間感情メタファーの強さとの関係を検討した。実験 1 では、参加者にポジティブおよびネガティブな語を空間的な枠の中に配置させた。その結果、高齢の参加者ほど、垂直軸に沿って両者をより明確に区別する傾向が見られた。実験 2 では、「上」や「下」などの基本的な空間語の感情価を評価してもらい、加齢効果が概念評価の変化に起因するのかを検討した。その結果、空間語の感情評価と年齢の間には有意な関係は認められなかった。これにより、垂直空間感情メタファーの強化は、概念的評価の変化ではなく、既に形成された身体的連合の再活性化と繰り返しによって生じることが示唆された。これらの結果は、身体化された認知的効果が時間の経過とともに顕著になるという考え方に対する実証的な支持を提供するものである。

Key words

space-valence metaphor, embodied cognition, aging, crowdsourcing, sensorimotor experience

1. Introduction

Since the mid-20th century, much of cognitive science has generally treated cognition as an abstract, symbol-based computational process, emphasizing that mental processes operate on symbolic representations independent of the body (Fodor, 1975), follow rule-based computations similar to computer processing (Newell & Simon, 1972), and primarily rely on internal information processing detached from bodily interactions (Neisser, 2014 (1967)). In contrast, Varela, Thompson, & Rosch (1993) argued that perception and motor systems play a more central role in cognition rather than merely serving as input mechanisms. They proposed that cognitive processes are shaped by sensorimotor interactions between individuals and their environment, with perception and action functioning as fundamental components of thought. Embodied cognition advocates that the way in which the physical body, nervous system, and sensory motor systems are organized shapes how we perceive and understand the world (Wilson, 2002). Systematicity between cognitive concepts is argued further in Barsalou's Perceptual Symbol Systems Theory (1999) that these arise from simulations in perception and action systems rather than being purely symbolic representations without any sensory basis. This is consistent with Conceptual Metaphor Theory (CMT: Lakoff & Johnson, 1980), which holds that our conceptual system is primarily metaphorical and is instantaneously grounded in physical experiences (Lakoff, 1993; Gibbs, 2005; Kövecses, 2002). To simplify abstract meaning and make it easier for people to grasp, these target domains are consistently mapped onto more concrete source domains that we gain from interacting with objects in the physical world.

1.1 Space-valence metaphors

Space-valence metaphors are a classic example of abstract conceptual mapping (Lakoff & Johnson, 1980). Positive and negative emotions are often associated with opposite poles along a given spatial axis; for instance, positive emotions are linked to "up" and negative emotions to "down". This connection is evident in both behaviour and language in daily life: people jump when they are happy and lower their heads when they are sad, while phrases like feeling up and feeling down provide evidence for the existence of this metaphorical structure.

Empirical studies provide strong support for the robustness of the space-valence metaphor. For example, spatial memory tends to be systematically influenced by emotional valence, with positive stimuli more often recalled in higher locations relative to negative stimuli (Crawford, Margolies, Drake, & Murphy, 2006). Similarly, evaluations of positive stimuli are evaluated more quickly when they appear in an upper position, while negative stimuli are evaluated faster when placed lower (Meier & Robinson, 2004). Additionally, when the emotional valence of words matches their spatial position, people evaluate them more positively, suggesting that spatial congruence enhances processing fluency and influences judgment (Schnall & Clore, 2004). Beyond cognitive processing, emotions also affect individuals' perception of space. Sasaki, Seno, Yamada & Miura (2012) found that emotional sounds modulate vertical vection: positive sounds enhance the sensation of upward motion. This suggests that emotions are not only associated with spatial concepts but can also shape spatial perception. Furthermore, the space-valence metaphor extends beyond cognition and perception to bodily behaviours. Stepper & Strack (1993) and Riskind & Gotay (1982) demonstrated that posture influences emotional experience, with more upright postures linked to positive emotions and slouched postures associated with negative emotions. Similarly, Oosterwijk and colleagues (2009) found that when individuals generate words related to "pride" or "disappointment", their body posture tends to become more upright or slouched accordingly, reinforcing the link between emotions and physical movement. This effect persists in localized bodily movements, as shown by Sasaki, Yamada, and Miura (2015), who found that hand movements in the vertical direction after viewing emotional stimuli influenced participants' evaluations of those stimuli; Kato, Imaizumi, and Tanno (2018) also provided support for this finding. Additionally, Sasaki, Yamada, and Miura (2016) demonstrated that after viewing positive or negative emotional images, individuals manipulating a vertical joystick tended to place the dot in the upper or lower part of the display, aligning with the emotional valence of the stimuli. Cross-linguistic and cross-cultural studies further confirm the universality of the space-valence metaphor, as people across different populations consistently tend to place positive words or objects in higher positions and negative ones in lower positions (Marmolejo-Ramos et al., 2013, 2016). Collectively, these findings suggest that the space-valence metaphor is not only deeply embedded in multiple cognitive processes but also exhibits strong cross-cultural consistency, providing strong evidence for its robustness and cross-cultural universality.

However, unlike the vertical axis, the relationship between space and emotion along the horizontal axis exhibits greater variability and plasticity (e.g., Casasanto & Chrysikou, 2011; de la Fuente, 2015a; 2017; de la Vega, Dudschig, De Filippis, Lachmair, & Kaup, 2013; Yonemitsu, Sasaki, & Yamada, 2023). Research on handedness demonstrates that right-handed individuals tend to associate "good" with the right side, while left-handed individuals associate "good" with the left (Casasanto, 2009, 2011; Casasanto & Jasmin, 2010; Casasanto & Henetz, 2012). Moreover, this association is not fixed within individuals. Casasanto & Chrysikou (2011) manipulated participants' hand use by requiring right-handers to wear a glove and complete tasks with their left hand. After a short period of adaptation, their space-valence bias shifted, resembling that of left-handers. This finding suggests that space-valence metaphors are not rigid but rather shaped by individual bodily experiences, supporting the Body-Specificity Hypothesis (BSH: Casasanto, 2009). According to this theory, abstract concept representation is influenced by bodily characteristics, meaning that individuals who interact with their physical environment in systematically different ways will develop distinct cognitive representations.

While the horizontal dimension exhibits such plasticity, altering vertical space-valence mappings appears much more difficult. This may be due to fundamental physical constraints, such as gravity, bipedal locomotion, and human body structure, which create shared vertical experiences across all humans. However, exceptions exist. In a study adapting the methodology of Marmolejo-Ramos et al. (2016), we examined four ethnic minority groups in China using a paper-based version of the task. While the Dai, Hani, and Zhuang participants exhibited a robust up-positive, down-negative bias, the Yao participants showed no significant space-valence metaphor preference (Zhu, Sasaki, Jiang, Qian, & Yamada, 2025a). To further explore this, we examined a key daily life characteristic of the Yao community: frequent uphill and downhill movements while carrying heavy loads. We hypothesized that this distinctive bodily experience could shape their space-valence mappings. To test this, we conducted a follow-up study with Chongqing Bangbang porters, a labour group with similar extensive experience carrying heavy loads up and down steep inclines. We also included university students as a control group. The findings mirrored those observed in the Yao participants; the Bangbang porters exhibited no significant vertical space-valence mappings, suggesting that repeated bodily experiences related to vertical movement while carrying heavy loads may disrupt or weaken conventional vertical space-valence metaphors (Zhu et al., 2025b).

1.2 The role of aging in embodied cognition

One critical factor that cannot be ignored in these findings is age. The groups that did not exhibit a significant vertical space–valence metaphor, the Yao and Bangbang participants were significantly older than the college student control group (Yao vs. control: 62.3 vs. 24.5 years, Welch's t (7.06) = 8.53, $p < .001$, Cohen's $d = 4.25$; Bangbang vs. control: 51.2 vs. 21.5 years; Welch's t (33.4) = 15.5, $p < .001$, Cohen's $d = 4.16$). This raises an important question: since the perceptual and motor systems that form the foundation of embodied cognition undergo development, maturation, and decline throughout the lifespan, different life stages are often associated with distinct sensorimotor and cognitive characteristics. Could this age difference have contributed to a weakening of their spatial-emotional associations?

Sensorimotor and cognitive skills develop rapidly during childhood, with interpersonal differences in the rate of learning. Children quickly learn new skills, advancing through a number of developmental stages through interaction with their environment and the gradual formation of sensorimotor patterns (Daum, Sommerville, & Prinz, 2009; O'Regan & Noë, 2001). On the other hand, aging is related to decreased adaptation in the cognitive and sensorimotor domains, thereby limiting older adults' ability to learn new sensorimotor relationships (Shephard, Berridge, & Montelpare, 1990; Greenwood, 2007). However, aging does not necessarily lead to a one-sided weakening of embodied cognition effects. While reductions in cognitive and sensorimotor flexibility may limit the formation of new associations (Calero & Navarro, 2007), long-term accumulation of sensorimotor experiences may strengthen existing embodied associations (De Scalzi, Rusted, & Oakhill, 2015; Loeffler, Raab, & Cañal-Bruland, 2016). Compared to younger individuals, who may exhibit stronger newly acquired embodied effects, embodied effects driven by previously established associations tend to intensify with age (Engelen, Bouwmeester, De Bruin, & Zwaan, 2011; Dekker et al., 2014).

As a reactivation-driven embodiment effect, space-valence metaphors are theoretically expected to strengthen with age. Research suggests that these metaphorical associations are already present in childhood and may persist into adulthood (Engelen et al., 2011; Casasanto & Henetz, 2012). With bodily development stabilizing and occupational and lifestyle patterns becoming more fixed, it remains uncertain whether these associations continue to evolve or remain largely stable in later life. However, research on embodied cognition across the lifespan, particularly in older adults, remains scarce (Loeffler et al., 2016). Based on existing evidence, the long-term accumulation of sensorimotor experiences is more likely to reinforce or consolidate pre-existing space-valence metaphors rather than weaken or restructure them.

Given this background, a critical question arises: does aging further enhance space-valence metaphors, or do they remain stable after adulthood? To address this issue, the present study systematically investigates the relationship between age and the strength of space-valence metaphors. Specifically, we aim to clarify whether space-valence metaphors progressively strengthen with accumulated experience or instead stabilize in adulthood.

2. Experiment 1

This study aimed to address the gap in research caused by insufficient data to establish a conclusive relationship between age and space-valence metaphors. Additionally, it sought to determine whether the significant age difference between the groups that exhibited no clear space-valence metaphor in our previous studies and the university student control group was a decisive factor in the absence of the effect.

To achieve this, we adopted the experimental design of Marmolejo-Ramos et al. (2013) and conducted an online survey spanning various age groups. The study tested two hypotheses: H1 predicted a positive correlation between age and the vertical positioning difference of positive and negative words, suggesting that the space-valence metaphor effect strengthens with age. H2 posited that the space-valence metaphor remains stable across adulthood. Additionally, if the correlation is not significant, we will conduct the Two One-Sided Tests for Equivalence (TOST) to assess whether the correlation between age and vertical spatial positioning differences is statistically equivalent to zero, providing a more rigorous examination of the stability of space-valence metaphors over time.

This study was preregistered, and all procedures were conducted in accordance with the preregistration (Zhu et al., 2025c).

2.1 Method

2.1.1 Ethics statement

This study received ethical approval from the Psychological Research Ethics Committee of the Faculty of Human-Environment Studies, Kyushu University (Approval No. 2018-002). Participants were informed that their participation was voluntary and that they could withdraw from the study at any point without providing a reason.

2.1.2 Participants

This online experiment was conducted via Yahoo! crowdsourcing platform. The instructions at the beginning of the task clearly stated that only individuals without cognitive or visual impairments should participate, and continuation was treated as implicit consent. Based on the predetermined sample size criteria and stopping conditions (see Sample Size Rationale and Stopping Rules below), along with the actual data collection process, a total of 192 participants were successfully recruited. All participants passed the instructional manipulation checks, and the final dataset included 192 individuals (Mean age = 49.22 years, SD = 10.64 , range = 20-78 years; 143 males, 47 females, 2 unspecified; 184 right-handed, 6 left-handed, 2 ambidextrous), all of whom were Japanese with normal vision. The age distribution in Experiment 1 was as follows: 8 in their 20s, 27 in their 30s, 60 in their 40s, 69 in their 50s, 22 in their 60s, and 6 in their 70s.

2.1.3 Stimuli and procedure

All participants voluntarily took part in this survey and were informed that they could exit the experiment at any point. The experiment was implemented using jsPsych (de Leeuw, 2015) and jsPsych-Psychophysics (Kuroki, 2021) or stimulus presentation and response collection in a web-based interface. After completing the initial instructions and providing demographic details such as gender, dominant hand, and age, the experiment transitioned into full-screen mode, and the main tasks commenced.

2.1.3.1 Word Allocation Task (WAT)

Participants first received instructions for the word placement task. They were instructed: “Please intuitively position the presented word anywhere within the square frame by clicking on the desired location.” It was further clarified that “You are free to place the word anywhere inside the frame. An ‘X’ will mark the selected position.” Additionally, participants were informed that the “vertical dashed line in the center of the frame is irrelevant to the task and should be disregarded while placing words.”

Following these instructions, participants placed 30 emotional valence words in a random sequence. Each word was displayed above a square containing a vertical dashed line, and participants clicked within the square to assign a location to the word (Figure 1: Left). To verify attentiveness, an instructional manipulation check was implemented after the placement of the 15th word. During this check, participants encountered a modified instruction: “No need to make a selection, simply click ‘next’ to continue.” After completing this step, they proceeded to place the remaining 15 words.

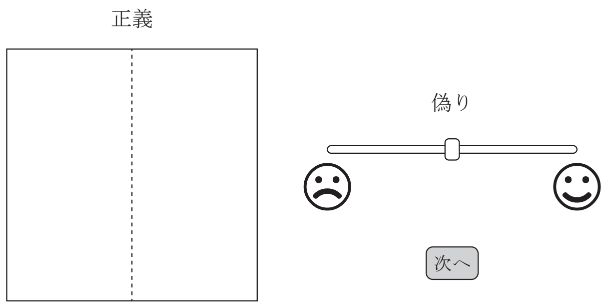

Figure 1: Words allocation task (left) and words rating task (right)

2.1.3.2 Word rating task

After finishing the WAT, participants moved on to the word rating task. They were instructed to “rate the emotional value of the displayed word.” It was specified that “Moving the indicator left represents a more negative evaluation (toward the sad face), while moving it right represents a more positive evaluation (toward the happy face).”

Participants then rated the 30 emotional words in the same order as they had appeared in the allocation task (Figure 1: Right). Similar to the previous phase, an instructional manipulation check like WAT was included after the 15th word to confirm that participants remained focused on the task. The study concluded with participants rating the final 15 words. Emotionally stimulating words are listed in the Appendix. Upon completion, participants received 20 PayPay Points as compensation for their participation in the research.

2.1.4 Sample size rationale and stopping rule

Statistical power analysis was performed with G*Power 3.1.9.7 to determine the necessary sample size to sufficiently examine the relationship between age and emotional valence representation in the spatial domains. Because space-valence metaphors are theorized to become more prevalent with age, a one-tailed test was chosen to examine for a positive trend. We chose a moderate effect size (0.3) for the Pearson correlation based on literature report of meaningful relationship between them. To meet common standards for statistical significance, the alpha level was agreed at 0.05, with a power ($1-\beta$) at 0.95 to obtain a high chance of confirming in the event of a real effect. The analysis showed that a minimum of 111 participants would suffice. Because the data collection was implemented using the crowdsourcing platform where quality of responses may differ, we increased the sample size by 50 % to take into consideration inconsistent, or low-quality data. Consequently, this adjustment resulted in a target sample size of 167 participants to allow sufficient power despite the inherent variability of crowdsourced data.

2.1.5 Stopping rule

The data collection was stopped when the number of participants exceeds the minimum by 20 %, i.e. 167 * 120 % = 200 participants.

2.1.6 Data availability

The preregistered study design, hypotheses, sample size rationale, experiment code, and analysis plans, along with the emotional word lists and datasets, are publicly available on the Open Science Framework (OSF; Zhu et al., 2024c).

2.2 Results

2.2.1 Data transcoding

Each word was mapped to a coordinate system, where (0, 0) and (100, 100) was the bottom-left corner and top-right corner respectively. The placement of each word in the word distribution task was noted with two values of positions on the X and Y axes with values between 0 and 100. Also, the other tasks were valence word evaluation tasks (here, words were rated on a 0-100 scale, where 0 was very negative, 50 was neutral and 100 was very positive).

2.2.1.1 Difference in vertical positioning between word categories

The average vertical position was calculated separately for positive and negative words for each participant. The difference was computed as the average vertical position of negative words subtracted from the average vertical position of positive words (Position Difference = Positive Position Mean – Negative

Position Mean). If the difference score is positive, it means that the participant placed words with a positive meaning higher on the vertical axis than words with a negative meaning. The higher the difference score, the more spatially separated the two classes of words were (up to +100). A score close to zero reflects weak vertical differentiation, suggesting little to no clear preference in positioning. Conversely, a negative difference score indicates that positive terms are ranked lower than negative terms, As the values become more negative, positive terms appear increasingly farther down the list (reaching as low as –100). Such a variable offers us a continuous representation of the metaphor in question and allows us to capture the hypothetical underlying representational relationship between spatial orientation and emotional valence.

2.2.1.2 Difference in emotional valence ratings between word categories

This variable, similar to the Difference in Vertical Positioning between Word Categories captures the difference in emotional valence ratings between the positive and negative words provided to each participant. The Valence Difference score is simply the average rating of negative words subtracted from the average rating of positive words (Mean Rating of Positive Words – Mean Rating of Negative Words = Valence Difference score). A higher positive score indicates stronger emotional positivity assigned to positive words (the highest possible difference is +100). Zero score means that the emotional valence of both types of words is not very different and creates no emotional attraction. On the other hand, a negative score means that positive words were scored for lower emotional positivity or higher negativity, approaching –100, indicating a more negative perspective. This metric gives an indication of how individuals decouple positive and negative words in terms of emotional valence.

Significant differences were observed across all comparisons. As shown in Table 1, positive words were positioned significantly higher than negative words in vertical space and significantly further to the right than negative words in horizontal space. Additionally, positive words received significantly higher ratings than negative words.

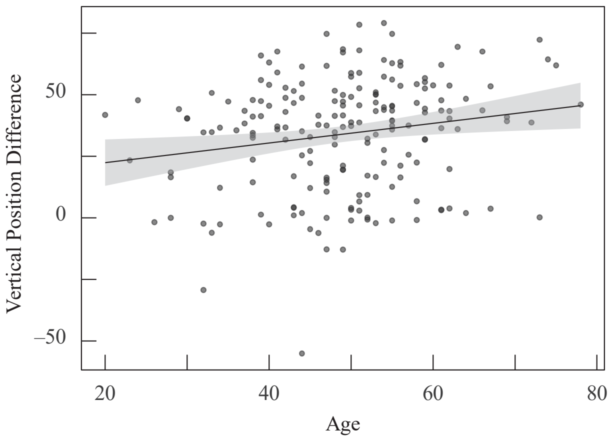

Figure 2: Relationship between age and the vertical spatial position difference of emotionally valenced words

Note: The black line represents a linear regression fit with a 95 % confidence interval (gray band).

Vertical Position: A one-tailed Pearson correlation analysis was conducted using R (Version 4.4.1; R Core Team, 2024) to examine whether age positively correlates with the difference in vertical spatial positioning between positive and negative words. The results revealed a weak but statistically significant positive correlation, $r(192) = .185$, $p = .005$. The 95 % confidence interval for the correlation coefficient ranged from 0.045 to 0.319. Fisher's z transformation indicated an effect size of $z = 0.19$, $SE = 0.07$.

2.2.1.3 Horizontal position

The same Pearson correlation analysis was conducted for horizontal spatial positioning as for vertical spatial positioning. The results revealed no significant correlation, $r(190) = –.106$, $p = .929$ (one-tailed), with a 95 % confidence interval of (–0.223, 1.000). Fisher's z transformation indicated an effect size of $z = –0.11$, $SE = 0.07$. These findings indicate that there is no evidence for a positive correlation, suggesting that age does not significantly influence the difference in horizontal spatial positioning.

A TOST equivalence test was performed using the TOSTER package (Version 0.8.4; Lakens, 2017) in R to determine wheth-

Table 1: Descriptive statistics and results of paired *t*-tests for differences in spatial position and ratings

Measure	Valence	Mean	SD	MD	95% CI (MD)	*t* (191)	*p*	Cohen's *d*	95% CI (*d*)
Vertical Position	Negative	31.16	12.7	–	–	–	–	–	–
	Positive	65.28	14.63	34.1	[30.9, 37.4]	20.63	< .001	1.49	[1.28, 1.69]
Horizontal Position	Negative	40.25	14.76	–	–	–	–	–	–
	Positive	59.81	14.28	19.6	[15.6, 23.5]	9.84	<.001	0.71	[0.55, 0.87]
Rating	Negative	20.54	10.53	–	–	–	–	–	–
	Positive	78.96	10.17	58.4	[55.6, 61.2]	41.09	<.001	2.97	[2.64, 3.29]

Notes: M = mean, SD = standard deviation, MD = mean difference (Positive-Negative), 95 % CI (MD) = 95 % confidence interval for the mean difference. All tests are two-tailed.

er the observed correlation fell within the equivalence bounds of ±0.1. The analysis revealed mixed results: the correlation was not significantly greater than the lower equivalence bound (t (190) = –0.09, p = .536) but was significantly smaller than the upper equivalence bound (t (190) = –2.85, p = .002). The 95 % CI for the TOST analysis ranged from –0.244 to 0.036.

These results indicate that the correlation is not significant, and the TOST equivalence test did not provide sufficient evidence to support that it falls within the predefined equivalence bounds of ±0.1. Under this specific equivalence criterion, the effect cannot be confidently classified as either negligible or meaningful.

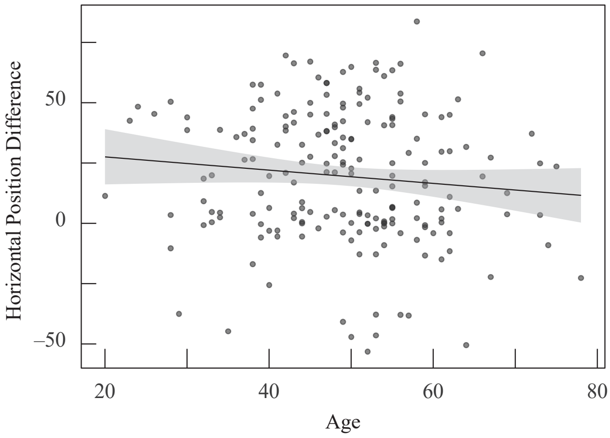

Figure 3: Relationship between age and the horizontal spatial position difference of emotionally valenced words

Note: The black line represents a linear regression fit with a 95 % confidence interval (gray band).

2.2.1.4 Rating scores

We further explored the relationship between age and rating differences using the same Pearson correlation approach. The results revealed a non-significant positive correlation, r (190) = 0.080, p = .134 (one-tailed), with a 95 % confidence interval of (–0.039, 1.000). Fisher's z transformation indicated an effect size of z = 0.08, SE = 0.07. These findings suggest no meaningful association between age and rating differences.

A TOST equivalence test was performed to determine whether the observed correlation fell within the equivalence bounds of ±0.1. The analysis revealed mixed results: the correlation was significantly greater than the lower equivalence bound (t (190) = 2.76, p = .006) but not significantly smaller than the upper equivalence bound (t (190) = 0.86, p = .393). The 95 % CI for the TOST analysis ranged from –0.062 to 0.219.

These results indicate that the correlation is not significant, and the TOST equivalence test did not provide sufficient evidence to support that it falls within the predefined equivalence bounds of ±0.1. This suggests that the effect cannot be confidently classified as either negligible or meaningful under this specific equivalence criterion.

2.3 Discussion

Experiment 1 examined the relationship between age and the spatial positioning of emotionally valenced words in a sample of adults aged 22 to 78. First, the placement of positive and negative words along the vertical axis replicated the findings of previous studies (Marmolejo-Ramos et al., 2013; 2016). Similarly, the spatial distribution of emotional stimuli along the horizontal axis was consistent with the results reported by Casasanto (2009) and the trends observed in its subsequent multi-lab replication study (Yamada et al., 2024), where positive stimuli were more frequently associated with the right and negative stimuli with the left. The Pearson correlation analysis results showed a small but significant positive correlation between age and the vertical spatial positioning difference, suggesting that older individuals differentiate positive and negative words more along the vertical axis. In contrast, Pearson correlation analysis did not reveal a significant relationship for horizontal spatial positioning, suggesting that age does not meaningfully influence differences along the horizontal axis. However, the TOST equivalence test did not provide sufficient evidence to confirm that the observed correlation entirely falls within the predefined equivalence bounds of ±0.1. These findings indicate that while no significant correlation was detected, it remains uncertain whether the effect size is small enough to be considered negligible within the specified equivalence range.

These findings further support the robustness of the vertical space-valence metaphor effect while also demonstrating that its strength increases with age. This is consistent with the view that embodied cognition effects driven by previously established associations tend to intensify over time (Engelen et al., 2011; Dekker et al., 2014). Moreover, it substantiates our previous findings (Zhu et al., 2025a; 2025b) that the absence of space-valence metaphor tendencies in older Yao and Bangbang populations was not due to aging effects. Instead, bodily experience and environmental factors have influenced their space-valence metaphor processing in a distinct manner.

However, the strengthening of space-valence metaphors with age may not only be explained by the idea that embodied cognition effects driven by previously established associations intensify over time. Another possibility is that the intrinsic emotional appraisal of spatial terms such as "up" and "down" changes with age, with older individuals perceiving "up" as more positive and "down" as more negative.

3. Experiment 2

As noted in the final part of the discussion in Experiment 1, it remains unclear whether this effect arises from changes in the intrinsic emotional appraisal of spatial concepts (e.g., perceiving "up" as increasingly positive and "down" as increasingly negative with age) or from the long-term reinforcement of sensorimotor associations. To investigate this, we conducted a second experiment using an online crowdsourcing platform. Following

Marmolejo-Ramos et al. (2013: Experiment 1), participants rated the emotional valence of four spatial terms. If age-related changes in ratings are observed, this would suggest that shifts in conceptual appraisal contribute to the strengthening of space-valence metaphors. Conversely, if no such pattern emerges, it would support the interpretation that these effects primarily result from repeated activation of pre-established embodied associations.

3.1 Method

3.1.1 Participants

Experiment 2 through the Yahoo! crowdsourcing platform. Before the experiment, all participants must confirm that they do not have cognitive or visual impairments. In accordance with the criteria for determining sample size and the predefined stopping condition in Experiment 1, No participant failed the instructional manipulation checks, 200 (Average age = 48.78 years, SD = 10.22, range = 20-74 years; 154 males, 45 females, 1 unspecified;185 right-handed, 10 left-handed, 5 ambidextrous) participants were successfully recruited for the experiment. No participant failed the instructional manipulation checks, and all were included in the data analyses. All Japanese with normal vision. The age distribution in Experiment 2 was as follows: 6 participants were in their 20s, 29 in their 30s, 77 in their 40s, 54 in their 50s, 30 in their 60s, and 4 in their 70s.

3.1.2 Stimuli and procedure

The procedure of Experiment 2 closely followed the word allocation task in Experiment 1, with the only modification being the re-placement of emotion words with four spatial terms: “up,” “down,” “left,” and “right.” After the presentation of 2 spatial terms, an instructional manipulation check was introduced before proceeding to the next spatial term.

Upon completion of the study, participants will receive 5 PayPay Points as compensation for their participation in the research.

3.2 Results

3.2.1 Data transcoding

Rating in the spatial term evaluation task (on a scale of 0-100, with 0 representing ‘very negative,’ 50 representing ‘neutral,’ and 100 representing ‘very positive’).

The calculation of the difference in emotional valence ratings for vertical (“up” vs. “down”) and horizontal (“right” vs. “left”) spatial terms followed the same transformation process as the emotional valence conversion in Experiment 1. Vertical Dimension: the difference score was computed as Up-Down; Horizontal Dimension: the difference score was computed as Right-Left.

As shown in Table 2, significant differences were found between spatial terms within each axis, with up rated significantly higher than down and right rated significantly higher than left.

3.2.1.1 Vertical dimension

The same Pearson correlation analysis as in Experiment 1 was conducted on the difference in emotional valence ratings for the spatial terms along each axis. The results revealed a near-zero correlation, r (198) = 0.003, p = .484 (one-tailed), with a 95 % confidence interval of (–0.114, 1.000). Fisher’s z transformation indicated an effect size of z = 0.003, SE = 0.071. These findings indicate that there is no evidence for a positive correlation, suggesting that age does not significantly influence the difference in emotional valence ratings between the vertical spatial terms “up” and “down.”

A TOST equivalence test was performed to determine whether the observed correlation fell within the equivalence bounds of ±0.1. The analysis revealed non-significant results: the correlation was not significantly greater than the lower equivalence bound (t (198) = 1.45, p = .074) and not significantly smaller than the upper equivalence bound (t (198) = –1.37, p = .086). The 95 % CI for the TOST analysis ranged from –0.136 to 0.142.

These results indicate that the correlation is not significant, and the TOST equivalence test did not provide sufficient evidence to support that it falls within the predefined equivalence bounds of ±0.1. Under this specific equivalence criterion, the effect cannot be confidently classified as either negligible or meaningful, suggesting that the influence of age on the emotional valence ratings of vertical spatial terms remains inconclusive.

3.2.1.2 Horizontal dimension

The same Pearson correlation analysis was conducted. The results also revealed a near-zero correlation, r (198) = –0.015, p = .581 (one-tailed), with a 95 % confidence interval of (–.131,

Table 2: Descriptive statistics and results of paired t-tests for spatial term ratings along each axis

Axis	Term	Mean	SD	MD	95% CI (MD)	t (199)	p	Cohen’s d	95% CI (d)
Vertical	Down	33.03	19.05	–	–	–	–	–	–
	Up	71.78	16.62	38.8	[34.5, 43.0]	17.84	< .001	2.171	[1.92, 2.43]
Horizontal	Left	44.07	23.27	–	–	–	–	–	–
	Right	65.13	20.28	21.1	[16.0, 26.1]	8.26	<.001	0.966	[0.80, 1.13]

Notes: M = mean, SD = standard deviation, MD = mean difference (Up-Down; Right-Left), 95 % CI (MD) = 95 % confidence interval for the mean difference. All tests are two-tailed.

1.000). Fisher's z transformation indicated an effect size of $z = –0.015$, $SE = 0.071$. These findings indicate that there is no evidence for a positive correlation, suggesting that age does not significantly influence the difference in emotional valence ratings between the horizontal spatial terms "left" and "right."

A TOST equivalence test was performed to determine whether the observed correlation fell within the equivalence bounds of ±0.1. The analysis revealed non-significant results: the correlation was not significantly greater than the lower equivalence bound (t (198) = 1.20, $p = .114$) and not significantly smaller than the upper equivalence bound (t (198) = –1.61, $p = .053$). The 95 % CI for the TOST analysis ranged from –0.153 to 0.124.

These results indicate that the correlation is not significant, and the TOST equivalence test did not provide sufficient evidence to support that it falls within the predefined equivalence bounds of ±0.1. Under this specific equivalence criterion, the effect cannot be confidently classified as either negligible or meaningful, suggesting that the influence of age on the emotional valence ratings of horizontal spatial terms remains inconclusive.

3.3 Discussion

Experiment 2 was designed to test whether the strengthening of space-valence metaphors with age observed in Experiment 1 was driven by changes in the emotional appraisal of spatial terms. The results showed no significant correlation between age and the emotional valence rating differences between the spatial term pairs "up-down" and "left-right," indicating that individuals' evaluations of these spatial terms remain stable over time. This suggests that the observed effect in Experiment 1 is more likely due to the reinforcement of existing associations rather than shifts in appraisal.

Additionally, the TOST equivalence test did not provide sufficient evidence to support that the correlation falls within the ±0.1 equivalence bounds, further suggesting that the influence of age on spatial term valence ratings remains inconclusive. These findings imply that the age-related effects on space-valence metaphors may be more influenced by long-term embodied experiences rather than semantic re-evaluation.

4. General discussion

The present study examined how age influences space-valence metaphors, considering two possible explanations: the reinforcement of embodied associations over time or changes in the emotional appraisal of spatial concepts. Experiment 1 demonstrated that older individuals exhibit stronger vertical space-valence metaphor effects, as evidenced by a greater difference in the vertical positioning of positive and negative words with increasing age. This suggests a developmental increase in the association between emotional valence and vertical space, reflected in a more pronounced spatial separation of positive and negative concepts. However, Experiment 2 found no significant relationship between age and the emotional appraisal of spatial terms, as ratings of "up," "down," "left," and "right" remained stable across ages. This rules out the possibility that the observed effect in Experiment 1 was driven by shifts in the emotional evaluation of spatial concepts. These findings support the idea that previously established embodied associations strengthen over time due to repeated activation rather than fundamental changes in conceptual appraisal.

Additionally, the results from TOST equivalence tests indicated that age-related changes in emotional ratings of spatial terms could not be confidently classified as either negligible or meaningful. This suggests that even if small variations exist, they are not substantial enough to account for the patterns observed in Experiment 1. Instead, long-term sensorimotor experiences and environmental interactions may play a more crucial role in shaping space-valence metaphor processing. For instance, occupational and lifestyle factors that repeatedly engage individuals in vertical spatial interactions (e.g., manual labor, frequent navigation of elevation changes) may serve to reinforce these metaphorical associations over time.

This study further elucidates the role of age in embodied cognition, particularly in the development of space-valence metaphors. While previous research has primarily focused on the use of metaphors in adulthood, investigations into middle-aged and older populations remain scarce. However, recent studies emphasize that understanding how sensorimotor experiences shape cognition requires a lifespan perspective (Loeffler et al., 2016). Our findings extend and support this view, demonstrating that age-related reinforcement plays a crucial role in the persistence and strengthening of space-valence metaphors throughout adulthood.

Embodied effects may stem from either newly formed associations or the reactivation of pre-existing ones. Younger individuals tend to be more adept at forming new sensorimotor connections, whereas older individuals rely more on accumulated experiences. The results of Experiment 1 support this distinction: as age increases, space-valence metaphors become more robust due to the progressive reactivation and reinforcement of existing associations (Engelen et al., 2011; Dekker et al., 2014). This suggests that space-valence metaphors are reinforced across the lifespan. In daily life, individuals continuously encounter language, social conventions, and bodily experiences, all of which contribute to strengthening the mappings between perception, movement, and emotion. For instance, upward movement is often associated with positive states (e.g., standing tall, success), while downward movement is linked to negative states (e.g., falling, failure). Such repeated co-occurrences make older individuals more likely to apply space-valence metaphors automatically, whereas younger individuals may still be refining these associations.

In contrast, horizontal space-valence associations appear to be more variable and less stable over time. Unlike vertical experiences, which are largely universal due to the effects of gravity and shared bodily postures, horizontal spatial associations are more influenced by cultural, linguistic, and individual differences. For instance, compared to vertical metaphors such as “rising” or “falling,” horizontal metaphors like “left-leaning” or “right-leaning” are less prevalent in language and daily experience. Additionally, writing direction may shape spatial preferences; for example, Hebrew and Arabic are written from right to left, the opposite of English, which may lead to different spatial biases. Furthermore, handedness also plays a role in shaping spatial preferences. Studies have shown that left- and right-handed individuals tend to exhibit opposite space-valence mappings (Casasanto, 2009; Yamada et al., 2024), yet these associations are not fixed and can shift when motor fluency is altered (Casasanto & Chrysikou, 2011; de la Fuente et al., 2015b; 2017). These factors introduce greater variability in horizontal spatial-emotional associations, making them less consistent and less likely to be reinforced over a lifetime. As a result, while vertical metaphors become more entrenched with age, horizontal metaphors remain more flexible and are shaped by environmental and cultural influences rather than aging alone.

This phenomenon may also explain why certain cultural groups, such as the Yao people and Chongqing Bangbang porters, do not exhibit space-valence metaphors despite their older age (Zhu et al., 2025a; 2025b). If aging alone strengthened these associations, then all older individuals should display this effect. However, the absence of such metaphors in these groups suggests that lifelong bodily experiences and environmental influences shape, or even inhibit, the development of these associations. Therefore, while aging may facilitate the reinforcement of embodied associations, those associations must first be acquired through accumulated experience.

4.1 Limitations and future directions

The primary focus of this study is the vertical dimension of space-valence metaphors, where age effects are most pronounced. As previously discussed, the horizontal dimension did not show a significant correlation. This asymmetry raises the question of whether future research could explore more refined experimental methods or introduce additional constraints (e.g., reaction time tasks) to detect space-valence metaphors along the horizontal axis more precisely. While this effect may be relatively weak, it could be more pronounced in languages and cultures where left-right distinctions carry emotional or evaluative connotations. For example, in Arabic culture, left-handed actions are subject to strong taboos, as the left hand is traditionally associated with impurity and is considered inappropriate for eating or drinking (see de la Fuente, 2015a). Additionally, future studies could incorporate alternative research methodologies to further uncover subtle horizontal space-valence associations that may exist in specific linguistic or cultural groups.

In Experiment 2, we included only four spatial terms (“up,” “down,” “left,” and “right”), which may not fully capture the impact of aging on the emotional appraisal of spatial concepts. In contrast, more diverse spatial expressions, such as “sky” and “overhead” versus “underground” and “beneath,” as well as quantified distance references like “at an altitude of 8844 meters” or “three levels below ground,” may better align with real-world spatial experiences and exhibit age-related variations. Drawing on the three-dimensional spatial allocation paradigm (Marmolejo-Ramos, Tirado, Arshamian, Vélez, & Arshamian, 2018), future research could go beyond traditional two-dimensional tasks and incorporate three-dimensional spatial positioning to examine how age influences spatial-emotional metaphors across multiple dimensions. This approach would not only allow for the investigation of age-related effects on vertical and horizontal space-valence metaphors but also provide important findings about whether depth (near-far) plays a role in spatial-emotional associations. Furthermore, experimental paradigms need not be confined to offline environments, and future studies could explore online spatial allocation tasks, such as presenting three-dimensional spaces in computer-based or virtual reality settings, to analyze how individuals form space-valence associations across different contexts, ultimately offering a more detailed understanding of the developmental trajectory of space-valence metaphors over time.

This study highlights a key question but does not specify which aspects of life experience might have the most lasting impact. Drawing on prior research (Zhu et al., 2025a; 2025b), future studies could explore whether individuals engaged in long-term spatially demanding occupations, such as porters, construction workers, or athletes, develop stronger or distinct space-valence metaphor effects in old age. Their prolonged bodily experiences may lead to spatial-emotional associations that differ from those observed in the general population. Further research is needed to clarify how occupational background, and daily spatial interactions shape these associations over time.

A constraint on the generality of this study is that it was conducted in Japanese, within a single cultural and linguistic context. While the strengthening of vertical space-valence metaphors with age appears to be a robust effect, it remains unclear whether this pattern would persist in languages with different spatial conceptions or in cultures that exhibit distinct space-emotion mappings. Cross-cultural studies could help determine whether the age-related reinforcement of embodied cognition is a universal phenomenon or one shaped by specific linguistic and environmental influences.

Another potential limitation concerns the use of Yahoo! crowdsourcing as the recruitment platform. Although this method enabled efficient data collection across a wide age range, it may have introduced sampling biases. For example, some older adults may have participated primarily to receive PayPay Points or as a way to pass the time, rather than from a genuine interest in the research. This raises concerns about whether the sample adequately reflects the general population. Additionally, although all participants successfully passed the instructional manipulation check, which ensured basic attention to task instructions, other screening relied solely on self-report. Specifically, the instructions clearly stated that only individuals without cognitive or visual impairments were eligible to participate, and participants were required to confirm this before beginning the task. However, it remains possible that individuals with undetected impairments still took part, which may have affected the precision and validity of the results. Future research should consider combining multiple recruitment strategies and incorporating objective screening tools, such as a visual acuity test for vision and a simplified, time-constrained Stroop task for cognitive function, to improve sample representativeness and data reliability.

Furthermore, we acknowledge that although this study employed a cross-sectional design covering a wide age range, the possibility of cohort effects cannot be entirely ruled out. Individuals from different generations have experienced substantially different social and developmental environments, and such generational differences may influence the formation and use of embodied metaphors. For example, as noted in our previous research (Zhu et al., 2025a), younger generations show a significantly stronger reliance on mobile networks and digital technologies, resulting in what has been referred to as an "information cliff" between age groups (Norris, 2001). In addition, recent decades have seen fundamental changes in occupational environments. As Acemoglu et al. (2022) point out, with the decomposition of complex production processes, tasks within existing occupations are being transformed: automation has replaced some human tasks while simultaneously creating new ones that require human input. These structural shifts may lead to a gradual replacement of physical labor with cognitive labor, thereby altering the sensorimotor experiences individuals accumulate in daily life. Furthermore, older individuals may differ substantially from younger cohorts in their experiential basis for interpreting metaphors related to technology or abstract concepts. Therefore, future studies may benefit from adopting longitudinal designs to more clearly distinguish the effects of aging from those of generational difference, thereby advancing a deeper understanding of the mechanisms underlying space–valence metaphor development.

Notably, the current study employed a relatively conservative equivalence bound (±0.1) for TOST equivalence testing, which may have influenced the conclusions. Setting stricter equivalence thresholds increases the likelihood of failing to establish equivalence, even if the true effect size is small but meaningful. Future studies should consider adjusting equivalence bounds based on empirical justifications and domain-specific effect size expectations.

Although substantial evidence supports embodied cognition, some researchers remain skeptical. Casasanto & Gijssels (2015), for instance, have pointed out that no direct neuroimaging evidence confirms that space-valence metaphors rely on sensorimotor systems rather than higher-level cognitive processes. Future neuroimaging research could investigate whether older adults show increased activation in sensorimotor-related brain regions when processing spatial-emotional concepts. Further studies using functional magnetic resonance imaging (fMRI) or transcranial magnetic stimulation (TMS) could help determine whether the observed correlations between space and emotion are truly mediated by sensorimotor systems or whether they primarily reflect abstract semantic associations.

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Appendix

- Positive words:
  嬉しい (joyful), 豊かな (wealthy/rich), 安全 (safe), 先進 (developed/advanced), 勤勉 (diligent), 清潔 (clean), 涼しい (cool), 暖かい (warm), 礼儀正しい (polite), 衛生的 (hygienic), 親切 (kind), 正義 (justice), 便利 (convenient), 乾燥 (dry), 正直 (honest).
- Negative words:
  悲しい (sad), 貧乏 (poor), 危険 (dangerous), 落後 (underdeveloped), 怠惰 (lazy), 汚染 (polluted), 暑い (hot), 寒い (cold), 野蛮 (barbaric), 汚い (dirty), 見知らぬ (unknown), 邪悪 (evil), 面倒 (troublesome), 湿っぽい (damp), 偽り (Hypocrisy/Falseness).

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