# Is the emotional mapping of lines caused by the motion they imply?

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## Abstract

Different patterns of lines can express different emotions, but the reason for the metaphor has not been fully revealed. Some studies speculate that this may be caused by the motion implied by lines. In order to verify this speculation, this paper conducts an experiment on the relationship between the emotional expression of lines and their implied motion. We created 87 different patterns of lines and visualized the motion implied by the lines as dynamic effects: a black dot with a trailing effect, which takes a line as its moving trajectory. Each line pattern produces slow and fast versions of moving animations. Therefore, there are three sets of test samples- static line patterns and their corresponding slow and fast moving dots. The subjects evaluate each sample by choosing descriptors from a list of 29 emotion words. The results show that the test samples can well cover the classical two-dimensional emotional space. The implied motion, compared with the static version, tends to shift towards the positive and high arousal in the 2-dimensional emotional space. In addition, the speed of the motion affects emotional arousal. It can be concluded that the emotional expression of lines is obviously related to their implied motion, however, their causality needs further study.

**Keywords:** line; line style; motion; emotion; perception; metaphor

## Introduction

The emotional expression of different patterns of lines has been studied for a long time. As early as 1921, Lundolm (1921) discovered that lines with different patterns could convey different emotions. He divided 48 adjectives into 13 groups with similar meanings and asked subjects to draw abstract lines to represent each adjective. He found that lines corresponding to synonyms of the same set showed great similarity among subjects. Lines dominated by sharp angles were usually associated with unpleasant and intense emotions, while lines dominated by rounded angles were usually associated with happy, calm emotions. Aftewards, some research further verified that straight and curved lines convey significantly different meanings. Straight lines are usually associated with direct, aggressive, bland, honest, industrial, ordered, strong, unnatural, adult, rigid, flexible, robust, and dignified. Curved lines are often associated with indirect, passive, pertaining to nature, childlike, romantic, soft, organic, safe, flexible, quiet, elegant, and feminine (Block, 2001; Hevneb, 1935). Some studies found that curved lines are more pleasant than straight or angled lines (Aronoff, Woike, & Hyman, 1992). However, people just show a preference for curves, there is no aversion to angles (Bertamini, Palumbo, Gheorghes, & Galatsidas, 2016). Lines and other forms can convey similar emotions if they show similar visual features. Through the experiment of matching words with one-dimensional lines, two-dimensional graphs, and three-dimensional geometries as symbols, Liu (1997) found that the more common ground different forms have, the more common symbolic meanings they share. People prefer circles to hexagons or irregular polygons (Cotter, Silvia, Bertamini, Palumbo, & Vartanian, 2017). For silhouettes of the same kind of object or meaningless contour, people prefer the curved version to the sharp version (Corradi et al., 2019). People prefer curved interior designs to angular ones. Body outlines with arcs and angles can evoke emotions evoked by ellipses and straight lines, respectively (Aronoff et al., 1992; Ibáñez & Delgado-Mata, 2013). However, the emotional expression of line patterns and their implied motions have not been well studied.

There have been many studies on the reasons for the perceptual and emotional mapping of lines, but there has not been a widely accepted explanation. Some studies have shown that the mapping between lines and their symbolic meanings can ignore individual differences such as artistic expertise and personality (Cotter et al., 2017; Lyman B., 1979; Silvia & Barona, 2009), and it can be cross-cultural (Charles E. Osgood, 1960). However, some other studies show that the evaluation of lines is related to learning and experience (Bar & Neta, 2008). The experiment of Franklin et al. (2019) suggested to some extent that the different feelings of straight lines and curves are related to the distribution of facial lines in different emotions. His first experiment found that angry faces had more radioactive straight lines, while happy faces had more circular curved lines. Sievers et al. (2019) explained that different lines, sounds, words, and human actions can evoke the same emotion was because there may be a multi-sensory coding-decoding system based on the frequency spectrum of stimuli. They explained that "the variation in the central tendency of the frequency spectrum of a stimulus—its spectral centroid—is used by signal senders to express emotional arousal, and signal receivers to make emotional arousal judgments". Some studies have suggested that different feelings and preferences for line patterns may be biologically determined since preferences are also present in newborns (Fantz & Miranda, 1975), mentally handicapped (Pustel, Sternlicht, & Derespinis, 1969), and other primates (Munar, Gomez-Puerto, Call, & Nadal, 2015). Fantz and Miranda (1975) found that newborns will gaze at a curved contour for a longer time than an angular one. They believed that this early preference was based on the different sensitivity of a group of cortical cells to continuous contours, curved visual patterns can stimulate the activity of cells more than straight visual patterns. However, the above studies have not tried verifying an explanation in traditional painting and calligraphy theory, that is, the emotion expressed by lines originates from the implied movement.

In fact, there has been a small amount of experimental study on the relationship between line and movement in emotional expression but is still very insufficient. Some opinions speculate that the pleasure delivered by the curve was caused by the relaxation of the eyeball, which will simulate the gliding motion when gazing at the curve. Stratto's (1902) experiments have been carried out to verify this theory, the results do not support this view. It shows that when people observe a curve, although the curve provides a smooth and continuous track, the watch path is irregular, variable, and even acute angular. Lundolm (1921) considered that lines seemed to imitate the motion expression of emotional states. Lines with long, low waves show a slow, feeble motion. The calmer emotions, such as sadness, languor, and quietness, were represented by these patterns of lines. Wavy lines with small, acute angles show rapid, intense motion. Strong emotions, such as anger or excitement, were represented by these patterns of lines. Farnsworth and Valentine (1969) explored the relationship between the emotional expression of lines and the emotional expression of the movement of the hands when drawing the lines. He asked testers to close their eyes and then tried to draw on the paper with some sample random curve graph freely. After each drawing, the testers evaluated the degree of pleasure of the action with their eyes closed. After 5 times drawing, testers looked at the lines drawn by them and evaluated the degree of pleasure of the lines. The results showed that the scores of motions were significantly higher than those of visual lines. Ibanez and Delado (2014) studied the emotional expression of the attributes of animated lines. They explored the relationship between emotional valence and arousal and visual attributes such as speed, line width, the amplitude of fluctuation, convergence, but the motion in their experiment was an additional special effect, rather than the "motion implied by the lines" as we refer to. In short, the known studies have not fully demonstrated the emotional relationship between lines and their suggestive movements, let alone explained its causality.

In summary, this study aimed to investigate the emotional relationship between emotions and the implied motion of lines. Significantly, our basic idea is to think of the lines themselves as tracks of motion and to visualize the motion for comparison, rather than attaching other dynamic effects to the lines. First, we created a set of horizontal orientation lines of different patterns and used them as the "trajectory of movement" to make the animation of black dots moving along the trajectory and realized two levels of speed-slow and fast. A total of three sets of stimuli were made and divided into two groups: lines, motions (including slow and fast versions). A subject was randomly assigned to one group and then evaluated 12 randomly chosen samples by selecting emotional words in the form of a checklist. Principal component analysis (PCA) (Jolliffe, 1986) was performed on the experimental data to reduce the emotional dimension, It is found that the first two dimensions after PCA match the classic 2D emotion model (Russell, 1980). By comparing the position of three sets of samples in the 2D emotional space, it can be found that the lines and implied motion have a transitional relationship. Specifically, the mapping from static lines to moving dots mainly affects the pleasure dimension, and the moving speed mainly affects the arousal dimension.

## Experiment

Figure 1 illustrates our experimental design. All our experimental data were collected in the form of online open paid questionnaires, and questionnaires were screened through the last question.

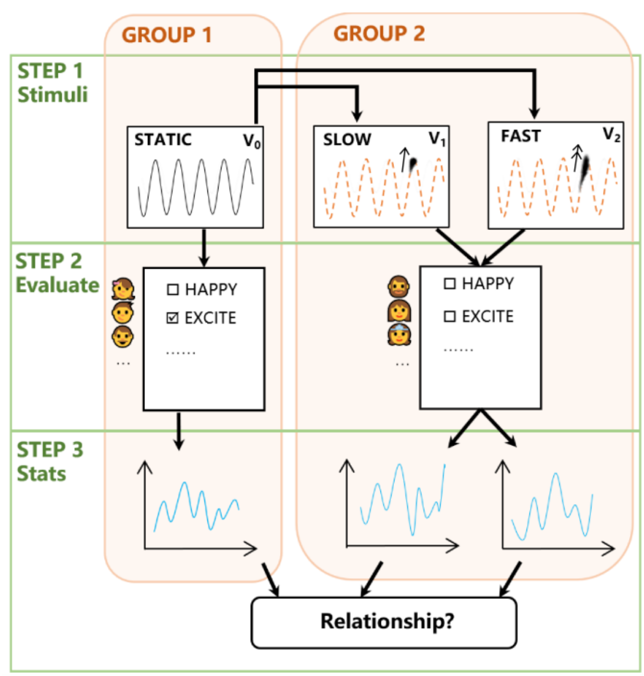


Figure 1: Experimental design.

### Stimuli

The test samples of the questionnaire I include 87 patterns of static horizontal lines. One author with a certain expertise in both programming and art training created these lines. The author tried his best to diversify line patterns. The 87 patterns were divided into 15 groups, each consisting of 3 to 8 patterns. The lines in the same group have a similar style but differ in details, such as fluctuation amplitude and rhythm density. Due to space limitations, only one sample of each group is shown in Figure 2. Each pattern is presented as a picture of 200x400 pixels.

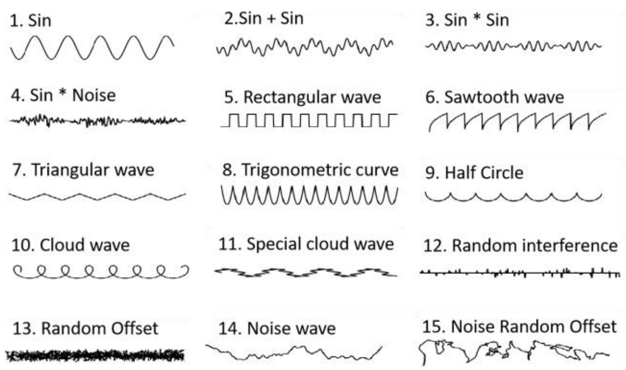


Figure 2: Test samples of 15 groups used in the questionnaire I.

There are 174 test samples for the questionnaire II. Each test sample is a black moving dot with a trailing effect, which takes one of the 87 patterns used in questionnaires I as the moving trajectory, with a speed of fast or slow, visualizing the motion implied by the static line. To prevent the lines themselves from interfering with the judgment, the motion trajectories of the black dots, which are the lines, are not shown. The speed of the black dot in the horizontal direction is fixed at 24 pixels/secs at a slow level and 48 pixels/secs at a fast level. In the electronic questionnaire, samples were displayed in the form of GIF figures with a resolution of 200x400 pixels. Because there is a certain gap between the motion trajectory of the black dot and the edges of the picture, the horizontal width of the track is slightly smaller than 400 pixels. Actually, the fast motion cycles about every 8 seconds, and the slow motion cycles about every 16 seconds. The frame rate of each GIF figure is 60 frames per second. The moving black dots in questionnaire II and their corresponding line patterns in questionnaire I are shown in Figure 3.

Figure 3: Black dots with trailing effect in questionnaire II. The red dotted line is the motion trajectory, which is not shown in the actual GIF figure. The solid black line in the lower right corner is the corresponding line pattern in questionnaire I.

### Evaluation

**Questionnaire Design** The test was presented in the form of an anonymous online questionnaire. The questionnaire consists of four parts:

i. Fill in age and gender.

ii. A checklist of emotional words to evaluate an emoji picture. The purpose is to familiarize the subjects with the type of question in the experiment.

iii. Evaluate samples with emotional words. This is the core part of the experiment. To avoid fatigue and evaluation inertia, a subject didn't need to evaluate all the samples but only need to evaluate randomly selected 12 samples. Therefore, each subject's third part consisted of 12 randomly chosen samples. Each sample is evaluated using a checklist of randomly permuted emotional words. The subjects can choose between 1 and 30 words in each checklist. Because we collected enough questionnaires, each of the 261 samples was guaranteed to be evaluated by at least 50 subjects.

iv. Screening question. The screening question was designed to screen out the questionnaire of subjects who did not finish the questions seriously. The question asked the tester to select 3 to 6 pictures from 12 items that are most significantly different from all the previous patterns. In the 12 items, 6 appeared in part iii, and the other 6 were significantly different from the sample patterns we tested.

**Emotion words** Both questionnaires used 27 emotional valence words which are derived from the related previous research literature (Cowen & Keltner, 2017; Mehrabian & Russell, 1974). They are admiration, adoration, appreciation, amusement, awe, awkwardness, boredom, anxiety, calmness, confusion, craving, disgust, pain, entrancement, envy, excitement, fear, horror, interest, joy, nostalgia, romance, sadness, satisfaction, sexual desire, sympathy, triumph. There were also two words for emotional arousal: quietness and intensity, and an "uncertain" option, which subjects could choose if they thought the shown sample does not show any emotion. Therefore, 30 words were provided in the checklist.

**Subjects** 1512 subjects completed questionnaire I, and 1812 subjects completed questionnaire II. Most of the subjects (82%) were between the ages of 18 and 40.

## Data analysis and results

We first screened out invalid questionnaires by the screening questions. Then performed PCA on the valid data, and discovered the relationship between the three sets of samples by analyzing the distribution of the three sets of samples in the principal emotional space. The emotional coverage of the three sets of samples was analyzed by calculating the distribution of the three sets of samples in the principal emotional space. The relationship of the three sets of samples is measured by the correlation in the principal emotional space.

We screen out invalid questionnaires by scoring the last screening question. The last question has 12 options, and we give positive scores to the correct choices and negative scores to the wrong options. By calculating the sum score of selected options, it can be judged whether the subject finished the questionnaire seriously. If the score of the screening question is less than 3, the questionnaire is judged as invalid. 510 of questionnaire I and 350 of questionnaire II were screened out, and the remaining 1002 of the questionnaire I and 1462 of the questionnaire II were collected as valid data.

Since the 29 emotional words are related, we performed PCA to reduce the dimensions. PCA results show that the first 5 principal components collectively explain 65.767% of the total variance. The first component was positively correlated with appreciation (principal component load: 0.697), interest (0.682), satisfaction (0.726), and negatively correlated with anxiety (-0.862), disgust (-0.851), pain (-0.884). The second component was positively correlated with excitement (0.854) and intensity (0.644), and negatively correlated with calmness (-0.753) and quietness (-0.742). The third, fourth, and fifth components were associated with adoration (0.534), awe (0.588), and sexual desire (0.79), respectively. Among them, the space formed by the first two components is similar to the classic 2D emotional space (Russell, 1980). In the 2D emotional space, the first dimension represents the emotional valence and the second dimension represents the emotional arousal. Such similarity proves the construct validity of our experiment.

The principal two dimensions cumulatively explain 48.763% variance, they correspond to Russell's 2D emotion model and can represent the core components of emotion. The relationship of three sets of samples in this space can reflect important information. To visualize our results, the first two principal components obtained through PCA were used as the coordinate axes to establish the 2D emotional space. The pairwise relationships between the three groups of samples are shown in 3 scatter plots in figure 4. The three colored markers in Figure 4 represent the three sets of samples. Every two samples corresponding to the same pattern are connected by a line segment, and the direction of the line segments shows the correlation between the three versions.

Two trends can be seen from Figure 4:

i. First, both the red and blue line segments tend to the right, indicating that after the line is transformed into motion along the line as a trajectory, the positive and the arousal of the emotion tend to increase.

ii. Second, the green line tends to go up, indicating that fast motion can show stronger emotional arousal than slow motion.

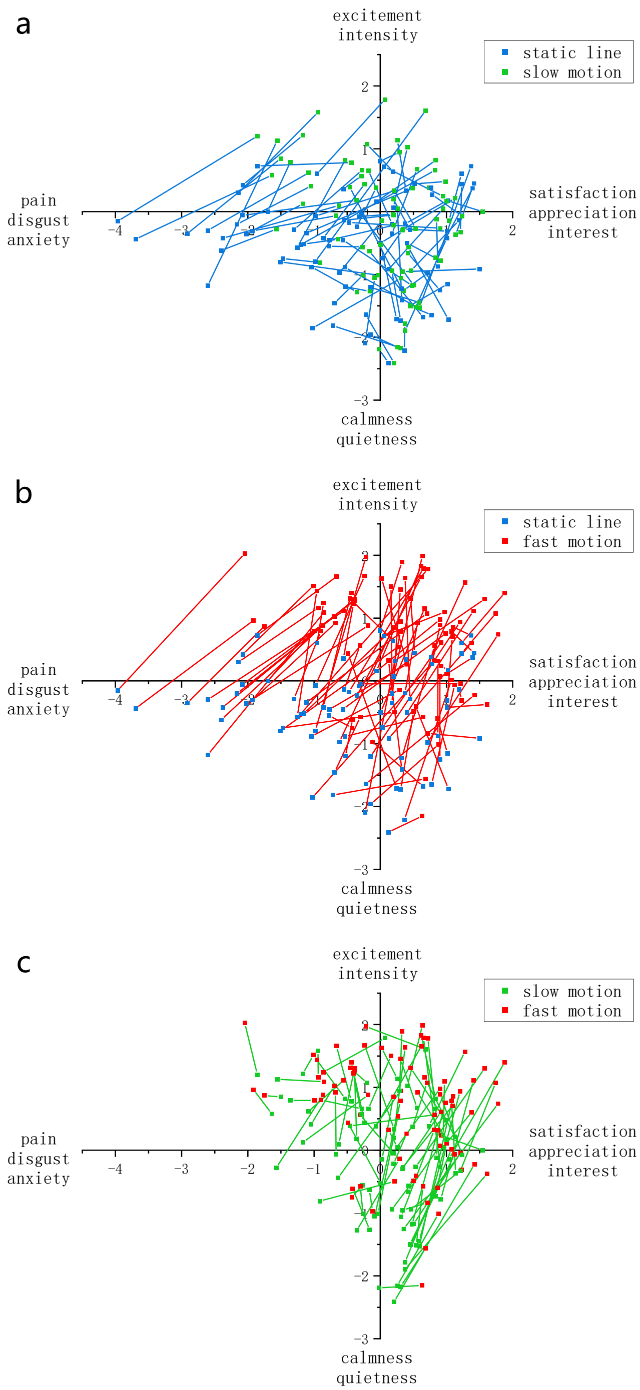


Figure 4: Projection of the three sets of samples in the emotional coordinate space. The comparison of static line and slow motion (a), the comparison of static line and fast motion (b), and the comparison of slow motion and fast motion (c).

We further analyzed the coverage range of all stimuli in the 2D emotional space. The scatter density plot is shown in Figure 5. The darker the color is, the more explicit the emotional expression exists in this area. Weak emotions with a Z-score less than 1 are represented inside the small circles, while strong emotions with a Z-score greater than 1 and less than 2 are represented between the large and the small circles. Among the 261 styles, 173 (66.3%) were outside the small circle. It can be seen from the scatter distribution that the samples we made with experience can achieve high emotional coverage, which also indicates that the samples we provided have good content validity.

We divide the two circles into eight regions with two crossed diagonal lines, and the distribution of the three sets of samples in the 8 regions is shown in Table 1. It can be seen from Figure 5 and Table 1 that there is a certain difference in the coverage range of the three sets of samples, which also reflects the above two basic laws. Additionally, the fast motion does not seem to be good at expressing negative emotions.

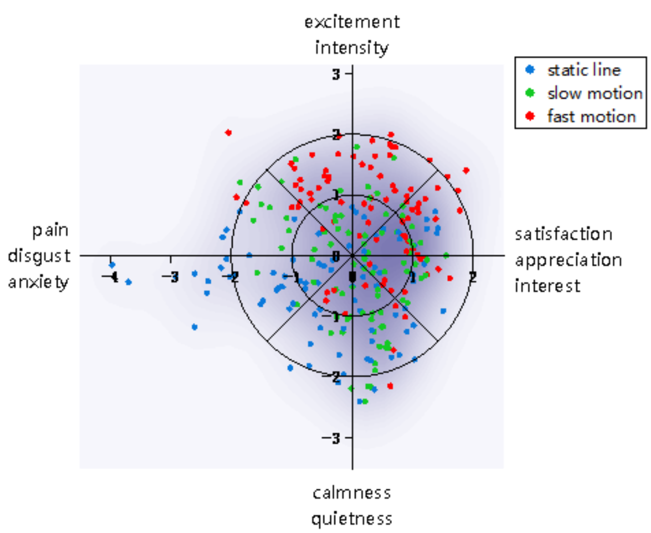


Figure 5: Distribution of three sets of samples in the first 2D principal component emotion space.

To explore the relationship between the three sets of samples. We calculated the Pearson correlation of 29 components produced by PCA. The results showed that there are significant strong correlations among the three sets of samples on the first component (corresponding to the emotional valence in classic 2D emotion space) (slow-fast: Pearson's coefficient is 0.805; slow-static: 0.813; fast-static: 0.795, all p less than 0.05); There is a significant relatively strong correlation on the second component (corresponding to the emotional arousal in classic 2D emotion space) (slow-fast: Pearson coefficient is 0.775; slow-static: 0.604; fast-static: 0.653, all p less than 0.05); On the third component (positively correlated with adoration), slow motion-fast motion and slow motion-static line was weakly correlated (Pearson coefficients are 0.381 and 0.305, respectively, all p less than 0.05), and there was no significant correlation between fast motion and static line. The correlations in the other component were weak (all Pearson coefficients are less than 0.3) or not significant (all p greater than 0.05).

## Conclusion

Different patterns of lines convey different emotions, which is deemed due to their implied motion in some empirical theories and research. The experiment in this paper proves that there is a significant correlation between the line and its corresponding motions in the expression of emotional valence and arousal. The experimental results also show that after the line is transformed into motion, especially for the fast motion, the emotion conveyed will move toward a more positive and higher arousal degree. Based on this result, and combined with some findings in neuroaesthetics shown that static lines can trigger a subconscious action imitation (Alessandra Umiltá, Berchio, Sestito, Freedberg, & Gallese, 2012; Sbriscia-Fioretti, Berchio, Freedberg, Gallese, & Umiltà, 2013), we speculate that when a beholder watches a static line, he/she will subconsciously imagine its corresponding motion, and thus feel the emotion encoded in it. However, the correlation between lines and their implied motion cannot directly infer that the emotion expressed by lines originates from their implied motion. Whether there is a causal relationship or a covariant relationship between the two needs further study. Besides, our experimental results show that discovered trends in 2D emotion space cannot cover the experimental samples' complete emotional performance, it also meets some previous research (Cowen & Keltner, 2017). In a richer emotional dimension than the 2D emotional space, the relationship between the lines and their implied motion needs further study.

Table 1: Distribution number and proportion of 261 samples in eight regions.

| Emotion | Static line | | Slow motion | | Fast motion | | Sum | |
|---|---|---|---|---|---|---|---|---|
| | Weak | Strong | Weak | Strong | Weak | Strong | Weak | Strong |
| Positive | 7(8%) | 10(11.5%) | 13(14.9%) | 12(13.8%) | 10(11.5%) | 21(24.1%) | 30 | 43 |
| Negative | 11(12.6%) | 25(28.7%) | 5(5.7%) | 10(11.5%) | 1(1.1%) | 5(5.7%) | 17 | 40 |
| Low arousal | 6(6.9%) | 23(26.4%) | 8(9.2%) | 22(25.3%) | 5(5.7%) | 4(4.6%) | 19 | 49 |
| High arousal | 5(5.7%) | 0(0%) | 10(11.5%) | 7(8%) | 7(8.0%) | 34(39%) | 22 | 41 |

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