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The Influence of Painting Composition on Human Perception

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Abstract

Artists have long explored the way in which we see the world, and they have developed their own tools to portray their vision. The present study investigated whether the compositional information in paintings, an artistic device invented by artists, is utilized when people view paintings. In Experiment 1, we categorized paintings depending on their compositions through experts' ratings. Using the stimuli from Experiment 1, Experiment 2 tested if the compositional information interferes with a target detection task. We found that the false alarms increased when the targets and distracters had the same composition compared to when they were different. Finally, Experiments 3A and 3B examined whether composition information influences the perceptual similarity of paintings. Through a multi-dimensional scaling analysis, we first showed that paintings with the same composition were proximately located in the mental space (Experiment 3A). Using this distance from the MDS analysis, we found that performance on the target detection task decreased as this distance became close (Experiment 3B). These results suggest that people make use of compositions in paintings, thus providing a possible link between artworks and the human visual system.

Keywords

Composition, paintings, spatial layouts, visual search, MDS

1. Introduction

Although art and science appear to have been developed independently, several scientists have recently suggested that both artists and scientists seek to understand in unique ways how people see the world (Cavanagh, 2005; Conway and Livingstone, 2007; Zeki and Lamb, 1994). While there is no doubt that the primary purpose of vision science to study the mechanisms underlying the human visual system, artists, using points, lines, planes, and colors as their tools, also have attempted to discover

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techniques that stimulate viewers' eyes. There is now significant evidence revealing that different types of visual art, particularly paintings, share basic properties that our visual brain is known to process, such as color (Livingstone, 2002), motion (Kim and Blake, 2007; Zeki and Lamb, 1994), statistical regularities (Graham and Field, 2007; Graham and Redies, 2010), and the physics of the visual world (Cavanagh, 2005). The present research focuses on our ability to perceive the spatial relations which artists successfully exploit through their use of composition in their paintings.

Of all pictorial principles, organizing the composition is the first step artists take when they begin to paint. They compose their works by placing figures in their proper locations so that relevant objects can be grouped together within a canvas. The application of composition has been greatly emphasized in art literature. In the words of an art historian, '... without composition, there can be no picture; ... the composition of pictorial units into a whole *is* the picture' (Poore, 1903, p. 20). With a well-structured composition, a painting can adequately reveal the relationships among the figures (Arnheim, 2004). For example, Andrea del Sarto, an Italian Renaissance painter, employed a pyramidal composition in his painting *Virgin and Child in Glory with Six Saints* (1528) with Mary and Jesus placed high in the center of the canvas and assisted by saints on the lower sides. In this painting, the relative importance of the figures in the scene can be inferred by their spatial positions such that the viewers can easily understand their relationships even without verbal explanations. Perception of spatial layouts in a scene is an important ability of humans. Evidence shows that people can rapidly categorize natural scenes using global properties such as the depth, openness, and perspective (Greene and Oliva, 2009a). Only 16–67 ms is required to obtain 75% categorization performance (Greene and Oliva, 2009b). Perception of the spatial layout is also found to aid further target processing. It has been shown that reaction times in determining the spatial relations of objects in a scene were faster when preceded by the target scene, suggesting that prior exposure to the scene could prime the spatial layout information (Sanocki, 2003; Sanocki and Epstein, 1997). Moreover, Chun *et al.* (Chun, 2000; Chun and Jiang, 1998, 1999) showed that targets which appear in repeated spatial configurations of distracters facilitate visual search performance even without participants' awareness of the distracter configurations. Their results indicate that global spatial configurations can be implicitly learned to guide our visual attention. Taken as a whole, these studies clearly show that humans take advantage of the processing of spatial information.

Do people make use of composition information when they observe a painting? Although artists' employment of pictorial composition in paintings has been discussed considerably within theory of art, the principle has not yet been empirically studied on the basis of human visual perception. Tyler (2007) introduced the concept of composition in art to vision science to suggest a relationship between the eye-centering principle in portraits (Tyler, 1998) and the pyramidal composition, yet the fundamental question regarding composition and the visual system remains to be tested. Thus, given the results from previous experiments showing our ability to perceive spatial layouts, the present research was conducted to investigate whether composition information embedded in paintings is utilized. Our predictions were twofold; if the visual system takes advantage of compositions, then (1) the detection of a painting would be disrupted if other paintings with similar compositions are presented together, and (2) the paintings with consistent compositions would be perceptually similar to each other.

To test our hypotheses, in Experiment 1 we first asked art experts to identify compositions embedded in paintings. The results obtained from Experiment 1 were used to categorize the stimuli in Experiment 2, in which novices were tested *via* a rapid serial visual presentation (RSVP) method to determine if a consistent composition interferes with target detection. Experiment 3A was conducted to examine whether paintings are represented based on their compositions using an identification learning task. The results were analyzed by a multi-dimensional scaling (MDS) technique. Finally, Experiment 3B supported, again using the RSVP method, that paintings proximately located in mind are similar at a perceptual level.

2. Experiment 1: Identifying Compositions in Paintings

The main goal of Experiment 1 was to define composition operationally. Three art experts were asked to identify compositions embedded in different Renaissance paintings. We were able to categorize most of them into four different composition types, with the rest defined as neutral. The result of the experts' ratings was later used in Experiments 2 and 3 as test stimuli.

2.1. Methods

2.1.1. Participants

Three art experts (all female) participated in the composition rating session. One of the experts had a master's degree in painting, and the others had degrees in art theory. All were paid fifty thousand Korean won for their participation.

2.1.2. Stimuli and Procedure

The stimuli were 495 scanned images of Early to Late Renaissance (1400–1600) paintings obtained from various sources. The Renaissance period was chosen because it was during this time that artists began to study compositional principles in paintings actively. Also during the Renaissance, the concept of the pyramidal composition was developed (Wölfflin, 1950). Among the stimuli, 245 images had landscape canvases — a greater width than height — while the others had portrait canvases — a greater height than width. Through an online survey website (http://www.surveymonkey.com), the experts first categorized each painting according to its composition by selecting one of the given choices. Possible answers in order were: horizontal, vertical, diagonal, pyramidal, and difficult to judge. The second question asked the experts to rate the fitness of the painting to the selected composition on a scale of 1 (slightly fit to the typical composition) to 9 (very well fit to the typical composition). Only one image was displayed on the screen with the composition choices, and the experts had to click an answer before the next stimulus was shown. The size of the longer side of each image was fixed at 800 pixels. There were 5 sections (100 images each; 5 images were later excluded from the main portion of the experiment due to repetition) in total, and the experts were instructed to respond with the first composition that came to mind. They could take breaks for as long as they wanted but only after finishing a section. A week was given to complete the entire task.

2.2. *Results and Discussion*

The results of the survey on composition identification are shown in Tables 1(a) and 1(b). We report only the data for the compositions that were actually used in Experiment 2 because not enough paintings were categorized as other compositions. Thus, images that were identified as a vertical landscape, a horizontal portrait, and a diagonal landscape and portrait, as well as those that were difficult to judge were considered as images on which experts could not agree. Among 245 landscape images, 57 were identified as having a horizontal composition (HOR-L; Horizontal Landscape) and 38 were categorized as having a pyramidal composition (PYR-L; Pyramidal Landscape) by all three experts. For the paintings that used a portrait canvas, all of the experts agreed on 28 images as having a vertical composition (VER-P; Vertical Portrait) and 25 images as having a pyramidal composition (PYR-P; Pyramidal Portrait). Two people agreed on 51 images as HOR-L, and 32 images as PYR-L. No agreement was reached on 67 images (NEU-L; Neutral Landscape). For the paintings with a portrait canvas, two experts categorized 78 images as VER-P, and 66 images as PYR-P. No agreement was reached (NEU-P; Neutral Portrait) on 53 images. The results of the fitness ratings of the compositions chosen for the paintings are shown in Fig. 1. As shown in this figure, the fitness rating scores were fairly high (over 5), suggesting that the images matched the given compositions well. The overall mean score was 7.33, and the individual scores for HOR-L, PYR-L, VER-P, and PYR-P were 7.33, 7.14, 7.46, and 7.4, respectively.

In Experiment 1, we were able to identify compositions in early Renaissance paintings that could be used as stimuli in the behavioral testing in Experiment 2.

Table 1.
Results of Experiment 1 on composition identification: (a) the number of images agreed upon by all three art experts for each composition category. These images were used as target stimuli in Experiment 2. (b) The number of images agreed upon by two art experts (HOR-L, PYR-L, VER-P and PYR-P) and those with no consensus (NEU-L, and NEU-P). These images were used as distracter stimuli in Experiment 2

	Composition	HOR-L	PYR-L	VER-P	PYR-P	NEU-L	NEU-P
(a)	Number of images	57	38	28	25		
(b)	Number of images	51	32	66	67	67	53

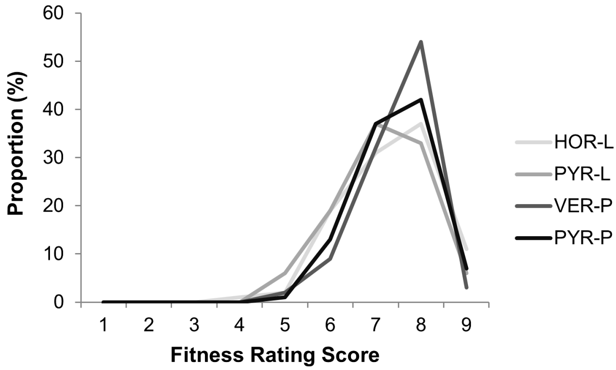

Figure 1. Proportions (%) of fitness rating scores of how close the paintings are to the typical compositions.

We found that the compositions were strongly related to canvases; artists frequently used combinations of a horizontal composition with a landscape canvas or a vertical composition with a portrait canvas. Thus, in Experiment 2, a composition was defined as any combination of compositions and canvases that corresponded to each other. As such, four levels were included in the composition condition (HOR-L, PYR-L, VER-P and PYR-P). Furthermore, the images on which all of the experts agreed were used as targets, and the images on which only two experts agreed were used as distracters in the formulation of the RSVP streams. Although agreed upon by only two experts, these images were used as distracters because many images were needed to create RSVP sequences with lowest number of image repetitions. Moreover, the fitness rating scores obtained by the two experts were as high as those of the targets. The no-agreement images were used as neutral distracters.

3. Experiment 2: The Effects of Composition on a Visual Search

The main goal of Experiment 2 was to test whether participants were able to make use of the compositional information. The underlying assumption was that novices could consistently perceive the composition categories that had been defined by experts. Within the RSVP paradigm, we aimed to determine the degree of distraction caused by the composition of an artwork during the search for a target image (Evans and Treisman, 2005). Visual search tasks were often used in previous studies to reveal the effect of spatial configurations (e.g. Chun and Jiang, 1998). The paintings categorized in Experiment 1 were used to create RSVP streams. We hypothesized that if novices could utilize the compositional information, they would then have difficulty detecting the target image in a RSVP sequence in which distracters are similar to the target in terms of composition. To be specific, there were two possible consequences. On one hand, participants would more easily discriminate a target from inconsistent distracters in target-present trials (increased hit rates in the inconsistent condition). On the other hand, they would more mistakenly report that the target was present due to consistent distracters in target-absent trials (increased false alarm rates in the consistent condition).

3.1. Methods

3.1.1. Participants

In Experiment 2, 12 undergraduate students (7 male, 5 female) from Yonsei University voluntarily participated as partial credit toward the fulfillment of their course. All of them had normal or corrected-to-normal visual acuity, and none had received formal education in the fine arts. All of the participants were naïve to the purposes of the study and gave written informed consent after receiving an explanation of the procedures. The study was approved by the Institutional Review Board of Yonsei University.

3.1.2. Apparatus and Stimuli

The images categorized in terms of their compositions in Experiment 1 were used in Experiment 2 (Table 1). All of the stimuli were gray-scaled and their RMS (root mean square) contrasts were matched to the level of 0.1 (Peli, 1990). For single-target rapid serial visual presentation (RSVP), images upon which all three judges agreed on the composition were used as targets, while those agreed on by only two were used as distracters. Images with no compositional agreement were used as neutral distracters.

Stimuli were presented on a linearized 21-inch HP P1230 CRT monitor set to a resolution of 1600 by 1200 at a refresh rate of 85 Hz. The experiment was programmed in MATLAB (MathWorks) using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). A forehead and chin rest was used to stabilize the heads of the observers. Participants were seated 90 cm from the monitor such that a pixel was subtended at a visual angle of 0.016°. The sizes of the stimuli were not controlled so as not to damage the original compositions embedded in the paintings. For the images with a landscape orientation, the width varied from 967 to 1024 pixels (from 15.3° to 16.19°) and the height from 325 to 1008 pixels (from 5.17° to 15.94°). The width of portrait images varied from 386 to 935 pixels (from 6.14° to 14.8°) and the height from 962 to 1024 pixels (from 15.22° to 16.19°). The center location of the images included in the RSVP sequence randomly jittered on the screen within a range of 13 pixels (0.21°) based on the upper left corner to reduce confounding caused by different stimuli sizes.

3.1.3. Design

Target–distracter compositional consistency was manipulated as a within-subject variable with three levels (consistent, inconsistent, and neutral). The same type of canvas was used within an RSVP sequence. For example, if the target was from HOR-L and the target–distracter relationship was consistent, then all of the distracters were also chosen from the HOR-L group. If the target was from PYR-P and the distracter condition was inconsistent, then the distracters were selected from the VER-P group. An experimental session consisted of 6 blocks of 96 trials each. All

3 types of consistency randomly appeared within each block. One minute breaks were given to the participants after the completion of a block. The orders of the distracter images in each RSVP sequence for a trial were randomized throughout the experiment. As dependent variables, accuracy and reaction times were measured.

3.1.4. Procedure

The procedure for the main experiment is shown in Fig. 2. The participants began each trial by pressing the space bar on the keyboard while a black fixation cross was on the screen. After the key stroke, the cross disappeared and a target image was presented in the center for 1000 ms. The cross then reappeared for 1000 ms, and the RSVP sequence began. Six images were temporally presented without any blank intervals, and the duration of each image was 75 ms. Target images were contained in the RSVP sequence in 50% of the trials, and they could be located either on the second, third, fourth or fifth frame with equal probability. At the end of each sequence, a blue fixation cross was presented, and the participants reported whether or not they detected the target in the sequence. They were asked to respond as accurately and as quickly as possible. They pressed the number 1 key as an indication of their detection of the target. When the participants did not detect the target, they pressed the number 2 key. If the response was correct, the color of the fixation cross became black as a signal for the beginning of a new trial. However, if the response was incorrect, a feedback sound was given and the next trial then began.

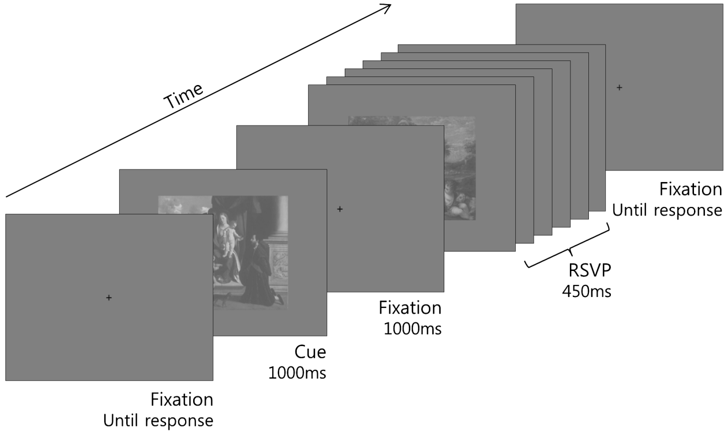

Figure 2. The procedure of Experiment 2: each trial was initiated with a black fixation cross when the participants pressed the space bar. A cue screen which indicated the target proceeded for 1000 ms followed by a black fixation cross for 1000 ms. Then, an RSVP sequence of 6 images was presented for 450 ms (75 ms each). A blue fixation cross appeared at the end for the participants to report whether or not they detected (*via* the '1' key for yes or the '2' key for no) the target within the RSVP stream.

3.2. Results and Discussion

3.2.1. Main Results

The results of Experiment 2 are shown in Fig. 3(a) and (b). The overall accuracy of the experiment was 88%. We separately analyzed the hit and false alarm rates to test whether the detection of a target was facilitated or hindered depending on the target–distracter consistency. A repeated-measures ANOVA revealed that there was no significant effect of target–distracter consistency on the hit rates, at $F(2, 22) = 0.387$, $p = 0.683$. However, we found a significant difference in the false alarm rates, at $F(2, 22) = 5.216$, $p < 0.05$. A Bonferroni *post-hoc* analysis indicated that this effect was due to the difference between the consistent condition ($M = 0.16$) and the other two conditions (the inconsistent ($M = 0.11$) and the neutral ($M = 0.13$) conditions). In other words, the participants more often erroneously reported targets in target-absent trials if the composition of the distracters was consistent with that of the targets. This result suggests that distracters with a composition in accordance with the target would interrupt the detection of the target more than inconsistent distracters would facilitate the performance, thus resulting in more false alarms in the consistent condition. The results for the reaction time did

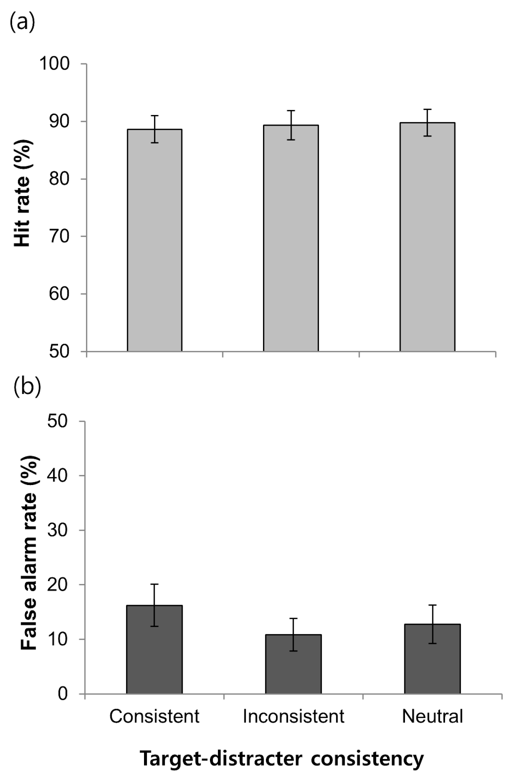

Figure 3. The hit (a) and false alarm rates (b) obtained from Experiment 2. Error bars denote the standard errors of the mean.

not reveal any significant main effect of consistency ($F(2, 22) = 0.290$, $p = 0.751$). This result suggests that there was no speed/accuracy trade-off.

The main goal of Experiment 2 was to determine whether the composition information created by artists is utilized when people observe paintings. Using the RSVP paradigm, we found that the target–distracter compositional consistency influenced the participants' target detection performance by increasing the false alarm rate in the consistent condition rather than increasing the hit rates in the inconsistent condition. This result indicates that the consistency of the composition information disturbs the detection of the target image, suggesting that people make use of the composition information embedded in paintings.

3.2.2. Control Analyses

Additional analyses were conducted to test whether there were any confounds that could explain the consistency effect found in Experiment 2 other than the compositions. First, we analyzed the intensity distribution of the images. The mean luminance of the images for each composition group did not significantly differ ($F(5, 485) = 0.64$, $p = 0.67$). An analysis of the skewness and kurtosis of the distribution revealed significant differences among composition groups (skewness: $F(5, 485) = 4.704$, $p < 0.05$; kurtosis: $F(5, 485) = 3.578$, $p < 0.05$). According to the Bonferroni *post-hoc* analysis, the effects were due to the differences between the pairs HOR-L *vs*. VER-P, HOR-L *vs*. PYR-P, and PYR-P *vs*. NEU-L for skewness (all p's < 0.05), and HOR-L *vs*. VER-P, and HOR-L *vs*. PYR-P for kurtosis (all p's < 0.05). Note that the differences were found across the canvas (landscape or portrait), while in our experiment the target and distracter images were chosen from an identical canvas within a trial. This suggests that none of the variables influenced the result.

Following Graham and Field (2007), we also analyzed the slope of the spatial frequency amplitude spectrum averaged over the orientation and plotted this on the log–log scale. Because the images were all different in size, we randomly selected a small patch (324 × 324 pixels) from each image for this analysis (324 was the smallest dimension among all paintings in this experiment). There was no significant difference in the slope of the amplitude spectrum among the compositions ($F(5, 485) = 0.794$, $p = 0.555$). The overall mean of the slopes was -1.24, which was consistent with the value (-1.23) found by Graham and Field (2007). This finding is interesting considering the differences in the samples chosen in their study as compared to ours. While we fixed the time period and provenance of the images to the early Renaissance in Europe, Graham and Field's samples contained a diverse range of time periods (from the 12th century AD to the contemporary era) and provenances (Europe, US, Asia and India). Consequently, the range of the artistic movement also was much more diverse in their paintings. Yet, the fact that the mean amplitude spectrum slopes were similar in both samples suggests, despite the diversity in the subclasses of art, that there are few differences in statistical regularities.

Next, we tested if the size and aspect ratio of the images could have affected the result. The analysis showed that there were significant differences in the size and aspect ratio of the images across different compositions (size: $F(5, 485) = 19.448$, $p < 0.05$; aspect ratio: $F(5, 485) = 355.123$, $p < 0.05$). The paintings with the HOR-L composition had the smallest image size, significantly different from all other composition categories (all p's < 0.05). The images in the VER-P group had the second smallest image size, significantly different from the PYR-L, PYR-P and NEU-P groups (all p's < 0.05). The HOR-L and VER-P were the two groups with the most distorted aspect ratio, both of them significantly different from their counterparts in the same canvas group (PYR-L and PYR-P, respectively, all p's $<$ 0.05). These results are not surprising because we manipulated the longer side of the images so that it was a maximum of 1024 pixels. Thus, the wide and narrow natures of landscape and portrait canvases, respectively, resulted in a smaller image size compared to close-to-square canvases. The distorted aspect ratio in HOR-L and VER-P is consistent with our observation in Experiment 1 that artists' selections of their compositions are related to the canvas they use. These differences in the image size and aspect ratio across composition categories, however, do not fully explain the result of Experiment 2. Although VER-P was significantly smaller than NEU-P, the comparison between the consistent and neutral conditions in VER-P did not yield a significant difference in the false alarm rate. Similarly, despite the difference in the aspect ratio between PYR-P and NEU-P, the false alarm rates in the consistent and neutral conditions in PYR-P did not differ significantly. Therefore, size and aspect ratio cannot entirely account for the consistency effect found in Experiment 2.

The gender ratio and the number of figures in the paintings were also analyzed. If all figures in a painting were male, then the painting was scored -1. Otherwise, it was scored 1. If there were no human figures, then the image was scored 0. The result showed that there was no significant difference in gender ratio across compositions ($F(5, 485) = 1.581$, $p = 0.184$), ruling out the possibility that gender confounded the results. The overall ratio was -0.38 suggesting that the paintings depicted male figures more than female figures. We found a significant difference in the total number of figures depicted in the paintings across compositions ($F(5, 485) = 13.135$, $p < 0.05$). The effect was caused by HOR-L and NEU-L paintings, which depicted significantly more figures than the others (all p's < 0.05), with no significant difference between the two. However, the number of figures cannot fully explain our results because there was a significant difference in the false alarm rate between the consistent and neutral conditions for HOR-L paintings ($t(11) = 2.530$, $p < 0.05$).

Finally, we tested if the emotion information in the paintings may have affected the consistency effect. The emotional value of a painting was determined by asking an additional group of participants ($n = 10$) to rate each painting on a seven-point scale regarding the emotional valence of a given painting (1: negative, 4: neutral, 7: positive). There was a significant main effect of composition in the emotion ratings ($F(5, 45) = 15.003$, $p < 0.05$). The PYR-L (4.2) and PYR-P (4.12) paintings expressed significantly more positive emotions than the HOR-L (3.74) and VER-P (3.82) paintings, respectively (all p's < 0.05). The comparison between PYR-L and NEU-L was also significant ($p < 0.05$). However, there was no significant difference in the false alarm rate between the consistent and neutral conditions for PYR-L ($t(11) = 0.329$, $p = 0.748$). Moreover, we found no significant correlation ($r = -165$, on average) between participants' false alarm rates in the RSVP task and the emotional rating differences (between target and distracters) of the images used for all compositions (all p's > 0.05). Thus, the emotional content of the paintings cannot fully explain our results.

In summary, the additional analyses of the low-level image features (intensity distribution, size, aspect ratio and spatial frequency amplitude) as well as the high-level image content (gender, number of figures and emotion) revealed that these image properties cannot entirely explain the results found in Experiment 2. Therefore, we conclude that the increase in the false alarm rate in the consistent condition was driven by the target–distracter compositional consistency.

4. Experiment 3A: The Effects of Composition on the Perceptual Similarity of Paintings

Experiment 2 showed that the target image detection performance in a RSVP stream decreased when the compositions of the target and the distracters were consistent. Experiment 3A was conducted to examine our second prediction — whether paintings within the same composition category were represented with shorter psychological distances in the mental space. We used an identification learning task in which participants were asked to memorize each painting with associated numbers. They were then tested on their image identification performance afterwards (Nosofsky, 1987). The hypothesis was that compositionally similar paintings would interfere with each other, thus resulting in more errors. The data was analyzed through MDS (Shepard, 1962a, b) to calculate the psychological distances among the represented paintings. The results showed that the mean distances among the paintings with defined compositions were significantly shorter than those of paintings with neutral compositions, suggesting perceptual similarity.

4.1. Methods

4.1.1. Participants

Nineteen Yonsei undergraduate students (5 male, 14 female) participated in this experiment. All had normal or corrected-to-normal visual acuity, and none reported receiving formal education in the fine arts. All of the participants were paid ten thousand Korean won for their participation after the experiment. They were naïve to the purposes of the study and gave written informed consent after receiving an explanation of the procedures. The study was approved by the Institutional Review Board of Yonsei University.

4.1.2. Stimuli and Apparatus

The same stimuli from Experiment 2 were used here as well, except here only 5 images were selected from paintings upon which all of the experts agreed and that were judged highly accorded to the given compositions. Thus, 30 images in total were used for the first 10 participants (see Table A1 in the Appendix for a complete list of the paintings). Another 30 images that were second highest in terms of their fitness ratings were selected for the remaining 9 participants. We used different sets of images to reduce the influence of the content and to ensure that the focus was on the effect of the compositions. The size of each painting was manipulated in the same manner used in Experiment 2, and the numbers assigned to the stimuli occupied about 80 pixels (1.6°). The apparatus was identical to that used in Experiment 2 as well.

4.1.3. Design

Composition was manipulated as a within-subject condition with 6 levels: 4 defined compositions (HOR-L, PYR-L, VER-P and PYR-P) and 2 neutrals (NEU-L, NEU-P). Five images were included in each condition; thus, 30 images in total were used. An experimental session consisted of two phases (learning and testing). An experimental block was defined as 30 trials, in which all 6 levels randomly appeared. All of the stimuli appeared only once in the learning phase, such that there were 30 trials of one block in total. In the testing phase, the blocks were iterated until the participants' performance levels were consistently above 90% for two continuous blocks. The maximum number of iterations was set to 10. On average, participants took 8.9 blocks to finish the experiment.

4.1.4. Procedure

The procedures for the two phases are depicted in Fig. 4. In the learning phase, 30 images were presented one at a time with their associated numbers ranging from 1 to 30. The task was to memorize each painting with the given number. At the beginning of each trial, a black fixation cross appeared on the screen until the participants clicked the wheel button on the mouse. Once the button press was detected, an image and a number were simultaneously presented side by side for 1000 ms. The images were always shown on the left side of the screen, and the numbers occupied the right side. The fixation cross then reappeared to indicate the beginning of the next trial. Different associations between numbers and images were used for each participant, and the images were shown only once. The experiment continued without any break to the testing phase.

In the testing phase, the participants were tested on the images they had previously learned. As in the learning phase, a fixation cross appeared on the screen, and the participants started the trial by clicking the wheel button on the mouse. On the next screen, an image was presented for 75 ms in the center of the screen followed by a number pad also located in the center. Using the left button of the mouse, the participants clicked on the numbers that they had memorized for the given painting. The numbers that the participants clicked were immediately shown at the bottom of

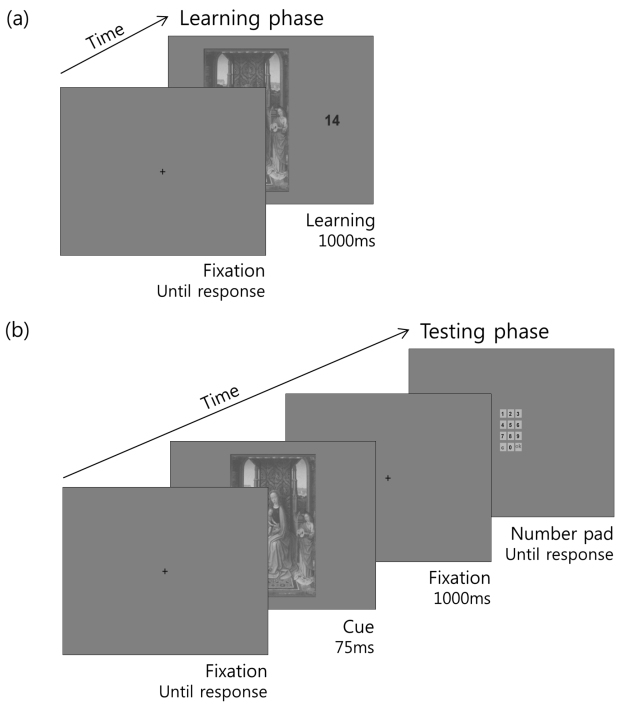

Figure 4. The procedure of Experiment 3: (a) examples of the timelines of the learning phase. A trial began with a fixation cross after a click of the wheel button on the mouse by the participant. Then, an image and a number appeared on the screen simultaneously for 1000 ms for the participants to memorize. (b) Examples of the timelines of the testing phase. A trial was initiated in the same way as the learning phase. A cue screen was presented for 75 ms followed by a fixation cross for 1000 ms. Then, a number pad was shown for the participants to click on the numbers that they had learned during the cue image.

the screen. Participants could click ‘c’ if they wanted to correct their responses, and when they were done, they clicked ‘ok’. If a response was incorrect, sound feedback was presented and the answer screen that the participants saw in the learning phase was provided for 1000 ms. Although there was no designated break time, participants had an opportunity to rest when necessary, as they initiated their own trials.

4.2. Results and Discussion

The data obtained were analyzed through the following procedure. Each participant’s responses were constructed into a 30 × 30 confusion matrix in which rows and columns indicated stimuli and responses, respectively. Thus, the numbers in each cell of the matrix represented the frequencies of the responses, and large numbers other than the numbers in the diagonal of the matrix would indicate more errors. As the numbers of block iterations differed among the participants, the frequencies in the confusion matrices were normalized according to the differences between the maximum and minimum frequencies. In addition, the information from

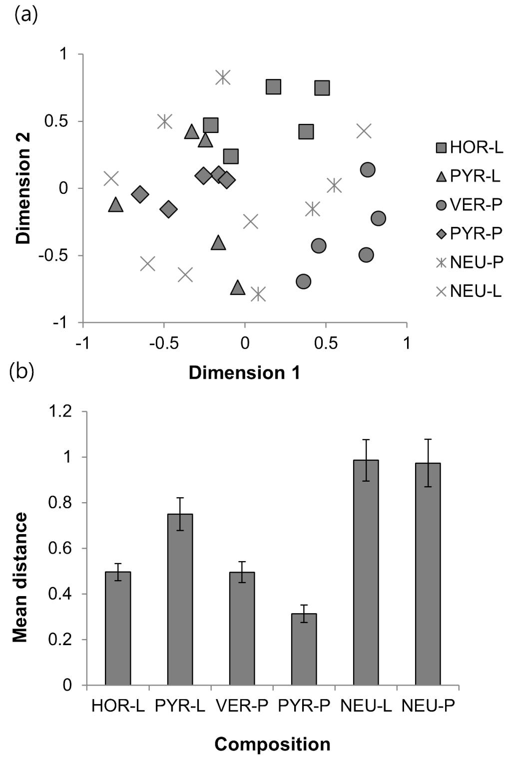

Figure 5. The results of Experiment 3A: (a) the result obtained by the MDS analysis. Two paintings with the same composition contributed to one point. (b) Mean distances among within-composition data points for defined (HOR-L, PYR-L, VER-P and PYR-P) and non-defined (NEU-L and NEU-P) compositions in the mental space.

the last block was excluded to eliminate data that reached a plateau. All of the confusion matrices obtained from the participants in both groups were summed up and then analyzed through the MDS (PROXSCAL) module in the statistical software SPSS.

The results obtained from the MDS analysis are illustrated in Fig. 5(a). Through a visual inspection, we found that the points that belonged to the defined composition conditions (HOR-L, PYR-L, VER-P and PYR-P) tended to group together in a two-dimensional space. In contrast, the points in the neutral conditions (NEU-L and NEU-P) appeared throughout the space. However, it should be noted that the data should be interpreted with caution, as the stress value was relatively high (Normalized Raw Stress $= 0.11$, Stress-I $= 0.34$) when only two dimensions were applied (see Note 1). Using the coordinates obtained from the MDS analysis, we were able to calculate the average distances of all possible combinations of points within a condition (Fig. 5(b)). The average distances for the defined composition groups were 0.5 (HOR-L), 0.75 (PYR-L), 0.5 (VER-P) and 0.31 (PYR-P), whereas the distances for the neutral conditions were 0.99 (NEU-L) and 0.97 (NEU-P). A univariate ANOVA indicated that there were significant differences among the distances ($F(5, 119) = 15.883$, $p < 0.01$). According to a Bonferroni *post-hoc* analysis, all of the defined compositions except PYR-L were significantly different from the neutral conditions, and no differences were found between them.

Experiment 3A found that the paintings with consistent compositions are closely located in the mental space with significantly shorter psychological distances. This result is in line with the findings of Experiment 2, in which the composition information in paintings was found to be utilized when people view paintings. Moreover, it can be inferred from Experiment 3A that the consistency effect found in Experiment 2 provides evidence of the perceptual similarity among the paintings.

5. Experiment 3B: Assessing the Perceptual Similarity of Paintings Using a Visual Search

In Experiment 3A, we employed a paired association task to test whether composition contributes to the perceptual similarity of paintings. However, due to the nature of the task, there may be effects which resulted from long-term memory or associative learning besides the perceptual similarity. In order to rule out these possibilities, in Experiment 3B we again employed the RSVP task, as in Experiment 2, using the psychological distances obtained from Experiment 3A. If the distances reflect the similarity on the perceptual level, then target detection by the participants will be disrupted when the psychological distance between the target and the distracters are close compared to when they are far. We also predict that this effect will result in more false alarms in the closest condition, consistent with Experiment 2.

5.1. Methods

The experiment was identical to Experiment 2 except as noted here. Twenty Yonsei undergraduate and graduate students participated (8 males and 12 females). The two sets of images (5 images each in 6 compositions) used in Experiment 3A were used as the stimuli. There was one condition (psychological distance) varied within subjects with four levels (very close, close, far and very far). From an image set, we randomly chose one image per composition category (6 images in total) as a target, and the rest of the images were used as distracters (24 images in total). The four distance levels were determined by dividing the distracters into four groups according to their distances from the target on the MDS map found in Experiment 3A. The same procedure was applied to the other set of images. It should be noted that there were more images that were consistent with the target in terms of their composition in each distracter set in the very-close condition compared to the very-far condition. Furthermore, emotional ratings did not differ across compositions in this experiment ($F(5, 48) = 1.477$, $p = 0.116$), unlike in Experiment 2.

Targets were present in half of the trials, as in Experiment 2, and the participants were presented with different target images in a Latin Square design. Because the images were repeated more than they were in Experiment 2, we decreased the stimulus duration to 50 ms in the RSVP sequence to reduce the effect of familiarity.

Additionally, a target image was never repeated for two continuous trials. An experimental session consisted of 96 trials in total.

5.2. Results and Discussion

Figure 6 illustrates the results of Experiment 3B. The overall accuracy was 75.5%, which was significantly lower than that of Experiment 2 ($F(1, 31) = 44.417$, $p < 0.05$). We speculate that this effect was caused by the decreased stimulus duration. A repeated-measures ANOVA showed that there was no effect of distance on the hit rates ($F(3, 57) = 1.746$, $p = 0.168$). However, we found a main effect of distance on the false alarm rates ($F(3, 57) = 5.474$, $p < 0.05$). A Bonferroni *post-hoc* analysis revealed that this effect was due to the significant difference between the very-close and very-far conditions. Participants had more false alarms if the distances between the target and distracters were close ($M = 0.28$) compared to when they were far ($M = 0.16$). The results for the reaction time did not reveal a significant main effect of distance ($F(3, 57) = 0.721$, $p = 0.544$). These results replicate the findings from Experiment 2, indicating that the psychological distances obtained in Experiment 3A indeed reflect the perceptual similarity of the paintings.

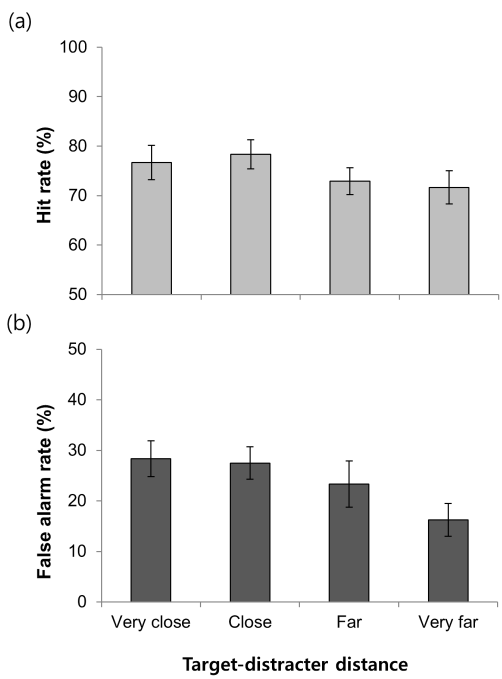

Figure 6. The hit (a) and false alarm rates (b) obtained from Experiment 3B. Error bars denote the standard error of the mean.

6. General Discussion

This study investigated people's perceptual use of composition in paintings, which has been exploited by artists throughout history. With Renaissance paintings of different compositions as categorized by art experts (Experiment 1), we tested target detection performance levels given a series of distracters. The results showed that people have difficulties when a target painting is included in distracters with a consistent composition compared to inconsistent or neutral compositions (Experiment 2). Furthermore, we found that paintings with consistent compositions are represented in our minds with shorter psychological distances (Experiment 3A), which reflect the similarity between paintings at the perceptual level (Experiment 3B). The results consistently show that people make use of the composition information embedded in paintings. Our research is in line with previous studies which showed our ability to process spatial layout information in visual scenes (Greene and Oliva, 2009a, b; Konkle *et al.*, 2010; Sanocki and Epstein, 1997) and in visual searches (Chun, 2000; Chun and Jiang, 1998; Jiang and Wagner, 2004).

One may question whether the consistency and similarity effects found in our experiments were due to interference caused by other visual characteristics in the paintings rather than their compositions. We have ruled out both low-level image statistics (contrast, intensity distribution, spatial frequency amplitude spectrum, size, and aspect ratio) and high-level image variables (gender ratio, number of people and emotional content) as the causes of our results. In addition, semantic information in paintings has been shown to be influential in the visual similarity of paintings. Graham *et al.* (2010) asked participants to rate the similarities of paintings using a paired comparison task and then analyzed the data *via* the MDS technique. They found that subject matter, such as inclusion of humans, best predicted people's judgments of similarities in paintings. However, in contrast to our experiments, their experiment was self-paced, allowing enough time for the semantic information to influence the results. The short stimulus presentation time in our experiments may have minimized the effect of the image content. Moreover, when the image content was controlled, the MDS analysis revealed the effect of the composition on the perceptual similarity of the paintings (Experiment 3A), which was supported by the results of the RSVP task (Experiment 3B). Previous research has shown that participants' target detection performance levels are impaired when the targets and distracters in RSVP sequences shared similar attributes, such as the eyes and mouths (Evans and Treisman, 2005). Composition information in paintings may be one of the visual attributes that is perceptually utilized in our mind and consistently shared across paintings.

The results from Experiments 2 and 3 indicate that paintings with defined compositions induced interference in target detection and identification learning due to perceptual similarities. A wide range of evidence shows that perceptual similarity is an important factor in processing visual inputs, especially when the grouping of stimuli is necessary. For instance, researchers have shown that attentional blink (Raymond *et al.*, 1992) is attenuated when the first target and the distractor following it in an RSVP stream are dissimilar in terms of their spatial and featural characteristics (Raymond *et al.*, 1995; Ward *et al.*, 1997). Not only the local discriminability between the first target and the distracter following it but also the overall discriminability between the first target and the rest of the distracters alleviated attentional blink (Chun and Potter, 1995). In a visual search, Duncan and Humphreys (1989) also emphasized the role of the target–distracter relationship. They suggested that the search performance would be impaired if the degree of visual similarity is increased between targets and distracters (T-D similarity) and decreased between the distracters themselves (D-D similarity). Correspondingly, in Experiment 2 in our study, the participants' performance levels were the lowest in a consistent condition in which T-D similarity was high due to the use of consistent compositions. However, T-D similarity affected the search performance more than D-D similarity because the false alarm rates for the neutral condition (low T-D and D-D similarities) were not significantly different from the inconsistent condition (low T-D and high D-D similarities).

The utilization of compositional information when people view paintings may be rooted in our ability to perceive the configurations or spatial layouts of objects in visual scenes. People are able to understand the spatial layout information of a scene rapidly (Chun and Jiang, 1998; Sanocki, 2003; Sanocki and Epstein, 1997), and there are specialized areas in the visual system that are used to process it (Epstein and Kanwisher, 1998). For instance, the human visual system begins to extract spatial information early during visual processing by analyzing the spatial frequency spectrum. It is known that each low and high spatial frequency conveys coarse and fine visual information, respectively (e.g. De Valois and De Valois, 1990). Thus, the coarse spatial information delivered by low-spatial-frequency channels allow us to encode the overall configuration of objects such that we can rapidly categorize scenes (Schyns and Oliva, 1994) and holistically process faces (e.g. Goffaux and Rossion, 2006). Also, the Parahippocampal Place Area (PPA), a scene-selective region in the ventral visual stream, may also play a role here. It has been shown that the activation in the PPA is stronger for fragments of a scene if they make up a coherent scene structure as compared to when they are randomly rearranged (Epstein and Kanwisher, 1998). That is to say, this area is sensitive to the geometry that composes a scene. We propose that, when people view paintings, our visual system may recruit the same mechanisms that process the spatial layout information in visual scenes to understand the composition information in paintings.

The present study supports the view that the creation of a visual work of art is based on the artist's exploration of how we see the world (Cavanagh, 2005; Conway and Livingstone, 2007; Zeki and Lamb, 1994). The assumption here is that artworks are created to be seen by humans such that the artists' strategies in creating them can help ease the processing of the visual information in the viewer's brain (Graham and Meng, 2011). In the same context, an artist's use of composition as a device in paintings indirectly reflects an awareness of our sensitivity to the space around us. Artists have picked up on our ability to extract spatial information from the environment and have used it in their paintings in turn to convey their intentions effectively. However, it is speculative at the moment as to whether the mechanisms underlying artists' use of composition in paintings and viewers' processing of that information are similar in nature. While the present study demonstrated novices' ability to utilize composition information consistently with images categorized by art experts, it does not necessarily indicate a direct relationship between the strategies used by the two groups. It is possible that novices' perception of composition is rather automatic and unconscious such that they have difficulty in explicitly categorizing paintings into different compositions like the experts. Further exploration of the influence of expertise on the perception of composition would have interesting implications regarding how the visual system processes spatial information as well as its role in the aesthetic experience.

Our research shows that people are able to make use of the compositional information embedded in artists' paintings. Using Renaissance paintings categorized according to their composition, we found that the visual search performance in RSVP streams was influenced by temporal distracters that had the same composition as the target. Moreover, when the participants' identification learning performance was analyzed through MDS, we found that the paintings with the same compositions were closely located in our mental space, indicating that the paintings were perceptually similar. Further research investigating the relationship between the human visual system and artworks should be able to determine what constitutes the composition in paintings and how spatial configuration interacts with object identity in creating meaning which in turn creates an aesthetic experience. These questions would eventually allow us to study the way people understand an image and form aesthetic preferences based on visual information created by artists.

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Note

1. The number of dimensions necessary to produce a highly satisfactory fit, above which any subsequent increase in dimension led to only slight decrease in the stress value, was 9 (Normalized Raw Stress = 0.009, Stress-I = 0.09). However, in order to represent the space graphically, a two-dimensional solution was used. Significant differences in the mean distance between the defined compositions and the neutrals were also observed when nine dimensions were used.

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Appendix

The paintings used in Experiments 3A and 3B are listed in Table A.1(a) and (b). The paintings with defined compositions (HOR-L, PYR-L, VER-P and PYR-P) were agreed upon by all three art experts regarding their compositions in Experiment 1 and were used as targets in Experiment 2. The paintings with non-defined compositions (NEU-L and NEU-P) were not agreed upon by the art experts and were used as neutral distracters in Experiment 2.

Table A.1.
List of paintings in the first (a) and second set (b) used in Experiments 3A and 3B

(a)

Composition	Artist	Title	Date
HOR-L	Andrea del Sarto	Four Saints: Predella with St. John Gualberto Watching the Ordeal by Fire of Pietro Igneo	1528
	Fra Angelico	Annalena Altarpiece	1445
	Hugo van der Goes	Adoration of the Shepherds	1480
	Unknown	Fleet of Ferdinand I in the Bay of Naples after the Battle of Ischia, July 1465	1472–1473
	Joris Hoefnagel	Fete at Bermondsey	1569–1570
PYR-L	Di Lese Benozzo	Virgin and Child with Saints	1452
	Bonifazio de'Pitati	The Holy Family with St. Francis, St. Anthony, Mary Magdalen, John the Baptist, and Elizabeth	1533
	Lorenzo Lotto	Portrait of an Architect	1540
	Fra Angelico	Predella Panel: Christ Rising from the Tomb	1430
	Vincenzo Campi	Pieta with St. Francis	Late 1570s
VER-P	Francesco Ubertini Bacchiacca	Portrait of a Young Lute Player	1520–1525
	Correggio	Abduction of Ganymede	1530
	Andrea Mantegna	St. Euphemia	1454
	Antonia Pollaiolo	David as Victor	1462
	Andrea Mantegna	St. Sebastian	1457–1459
PYR-P	Ambrogio Bergognone	Madonna Enthroned with Saints	1485
	Jan van Eyck	Madonna in her Chamber	1435–1436
	Giovanni Bellini	Virgin and Blessing Child	1475
	Gerard David	Enthroned Virgin and Child	1590–1595
	Paolo Veronese	Portrait of a Nobleman	1549–1550
NEU-L	Fra Angelico	Predella: Episodes from the Life of St. Nicholas of Bari	1437
	Lucas Cranach	Portrait of Melanchthon	1559
	Sassetta	Procession of the Magi	1568–1571
	Unknown	An Allegory of the Reformation	1568–1571
	Andrea Mantegna	Dead Christ	1490
NEU-P	South German Master	Regina Peter	1552
	Unknown	Entombment	1405
	Jacopo Tintoretto	Portrait of a Man as St. George	1540–1550
	Giorgio Vasari II	Massacre of Colligny and the Huguenots on St. Bartholomew's Day	1572–1573
	Bartolomeo di Giovanni	Life of St. Benedict: St. Benedict Blessing the Cup of Poison Which Shatters	1488

Table A.1.
(Continued)

(b)

Composition	Artist	Title	Date
HOR-L	Filippo Lippi	Disputation with Simon Magus and Cruxifixion of Peter	1427
	Domenico Ghirlandaio	Sistine Chapel: The Calling of the First Disciples	1480
	Luca Signorelli	The Marriage of the Virgin	1490–1491
	Giovanni Bellini	Sacred Allegory	1490
	Pieter Brueghel	Peasant Wedding	1568
PYR-L	Dosso Dossi	The Holy Family with the Young St. John the Baptist, a Cat, and Two Donors	1512–1513
	Hieronymus Bosch	The Hay Wain (center: lovers)	1490
	Fermo di Stefano Ghisoni	Diomedes Fighting Ideus and Phlegeus	1538–1539
	Di Lese Benozzo	Virgin and Child Enthroned Among Angels and Saints	1461
	Giovanni Bellini	Virgin and Child between the Baptist and St. Elizabeth	1490
VER-P	Pellegrino Tibaldi	St. Margaret of Antioch	1558–1561
	Unknown	Portrait of Emanuele Filberto	1561
	Ercole de'Roberti	St. Jerome in the Wilderness	1470
	Benvenuto di Giovanni	St. John Gualberto and the Crucifix	1470
	Domenico Ghirlandaio	Sassetti Chapel: Portrait of Francesco Sassetti	1485
PYR-P	Perugino	Madonna and Child with Saints Lawrence, Louis of Toulouse, Herculanus, and Constant	1495–1496
	Antonia Pollaiolo	St. Sebastian	1475
	Robert Campin	Madonna in Glory	1430
	Vincenzo Foppa	Madonna of the Drape	1465
	Fra Bartolommeo	Mystic Marriage of St. Catherine	1512
NEU-L	Giovanni Bellini	Dead Christ with St. John and the Virgin	1467–1471
	Domenico Beccafumi	Publius Mucius Sentencing his Fellow Tribunes to be Burned	1534–1535
	Dosso Dossi	Landscape with Saints	1527–1528
	Stradanus	Gioco del Calcio in Piazza Maria Novella	1562–1571
	Konrad Witz	St. Christopher	1450
NEU-P	Filippo Lippi	Madonna and Child with Two Angels before a Landscape	1465
	Jan van Scorel	Lamentation over Christ	1535–1540
	Petrus Christus	Death of the Virgin	1455–1460
	Giovanni di Paolo	St. John the Baptist in Prison Visited by Two Disciples	1455–1460
	Fra Angelico	Coronation of the Virgin	1482