Motion influences the Effects of Systematic Chromatic Changes

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Abstract

One example of color constancy is color transparency: when a surface is seen both in plain view and through a transparent overlay, the visual system still identifies it as a single surface. Previous studies suggest that color changes across a region of an image that can be described as translations and/or convergences in a linear trichromatic color space lead to the perception of transparency, but other transformations, such as shear and rotation, do not. Recently, other studies have added motion to their stimuli, claiming that this enhances the transparency effect.

We tested whether complex configurations and motion are neutral with respect to the effects of systematic color changes. We defined several experimental conditions: a static versus moving stimulus condition, a simple (bipartite stimuli) versus a more complex configuration (checkerboard stimuli), equiluminant, filter and illumination overlay conditions. Different absolute color changes (vector lengths) were also chosen and varied systematically within the gamut of the monitor.

The main results show that motion influences observers' responses for translations independently of stimulus complexity, luminance conditions, and vector lengths. A strong effect is observed for divergences that induce transparency perception in moving checkerboard conditions. However, while shears in a moving bipartite configuration tend to be transparent, this effect is completely cancelled for checkerboard like stimuli, even in motion. Finally, neither motion nor complex configuration effects have been found for convergences.

Introduction

Several studies [1-4] have suggested that color changes across a region of an image that can be described as translations and/or convergences in a linear trichromatic color space lead to the perception of transparency, but other transformations, such as shear and rotation, do not. Since color changes that describe a translation in color space can be considered to converge to a point at infinity, one speaks generally of the *Convergence Model* of transparency [2].

In a previous study, we found that under certain conditions, even divergences and shears may appear transparent [5]. Hupé et al. [6] have added motion to their stimuli, showing that this enhances the transparency effect. They showed that static non-transparent stimuli may appear transparent in motion. It appears that luminance cues have a weak influence on the perception of motion transparency. Moreover, segmentation based on motion can override conflicting luminance and color cues.

Khang and Zaidi [7] used backgrounds simulating a wide variety of spectral reflectances, spectrally reflective filters and equal energy light. Background materials were simulated as overlaying a circular region and moving along a circle. They pointed out that a moving filter has the advantage of covering a larger sample background of material than a static filter of the same size and noted as well that the movement of filters greatly enhances the perception of a transparent layer.

We are interested in studying whether similar trends in motion transparency could be found with respect to the chromatic changes. Because Hupé et al. [6] and Khang and Zaidi [7] have proposed two types of stimuli with different complexity, we have defined a simple and a more complex configuration to show to the subjects.

We performed two experiments, one with a bipartite like stimuli, the other with a checkerboard like configuration. We have studied a variety of chromatic transformations, changes in elevation from the equiluminant plane, with different vector lengths (color changes) for static versus motion overlays.

Our main results show that complex configurations and motion have an effect on translations, but not on convergences. A strong effect is also observed for divergences that induce transparency perception in moving checkerboard conditions, but do not in the other conditions. Finally, shears in a moving bipartite configuration tend to be transparent, but this effect is cancelled for checkerboard like stimuli, even in motion.

Method

All experiments were performed on a Barco PCD-321 monitor connected to a Dell Precision 330. The monitor has a resolution of 1280 x 1024 and ran at 75Hz. Calibrations were performed with a Minolta CS1000 spectroradiometer to find the best correspondence between linearized monitor RGB and the CIE XYZ space. Experimental stimuli were created with OpenGL.

The stimulus consisted of a bipartite field/checkerboard (10x10 deg.) overlaid by a bipartite field/checkerboard (5x5 deg.) displayed in the center of the monitor (Figure 1). Stimuli were static or moved in a circular way (2 deg. radius, centered on the middle of the figure). The same movement was kept constant for all trials, with a speed of 120 deg. per second. The rotation remained clockwise in all cases.

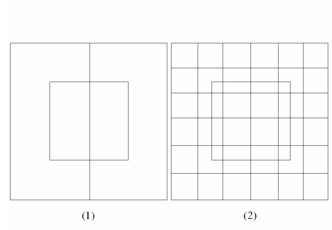


Figure 1. Example of a bipartite field (1) and a checkerboard stimulus (2). The smaller square moved clockwise during the motion experiments.

The color changes are described in terms of XYZ vector fields. Four chromatic transformations were considered: pure translations (Eq.1), pure convergences (Eq.2), shears (Eq.3) and divergences (Eq.4) (see Figure 2).

$$b_{P,Q} = a_{P,Q} + t \qquad (1)$$

$$b_{P,Q} = (1-\alpha)\, a_{P,Q} + \alpha g \text{ , with } 0 < \alpha < 1 \qquad (2)$$

$$b_{P,Q} = a_{P,Q} + t \text{ and } b_{P,Q} = a_{P,Q} - t \qquad (3)$$

$$b_{P,Q} = (1-\alpha)\, a_{P,Q} - \alpha g \text{ , with } 0 < \alpha < 1 \qquad (4)$$

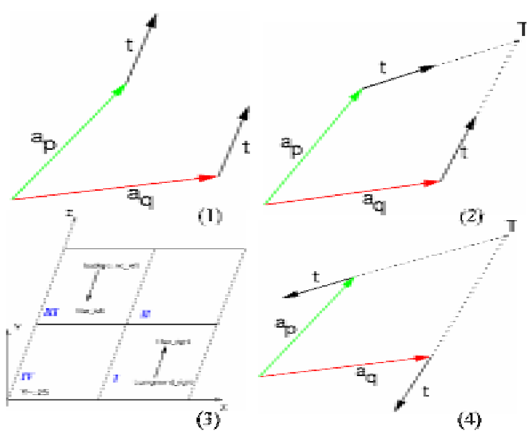


Figure 2. Example of translations (1), convergences (2), shears (3) and divergences (4).

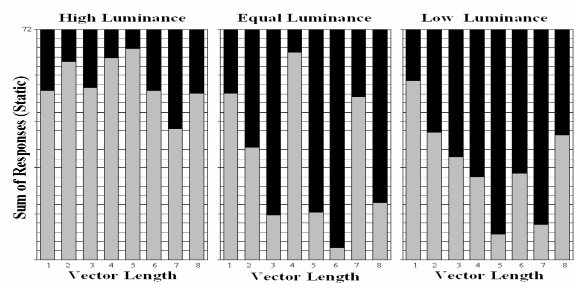
A total of 1152 stimuli were presented for each bipartite field or checkerboard experiment, with 2 motion conditions (present or absent), 3 luminance levels (vectors point to a higher, equal or lower luminance), 8 vector lengths and 6 color samples for each stimulus.

Four color normal observers were tested. The set of all patches was presented in a randomized sequence. For each patch, the observer judged whether the overlay was transparent or not. Each session was repeated three times. Pearson chi-square statistics (χ^2) were computed for all hypotheses.

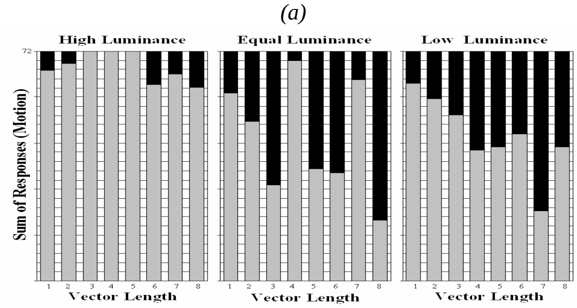
Results

Experiment 1: Bipartite field like stimuli

Figures 3-6 summarize the responses of the observers for translations, convergences, shears and divergences, for the bipartite configuration experiment. The three plots present the cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static stimuli (a). The same configuration for motion stimuli results is presented in Figures 3-6 (b).

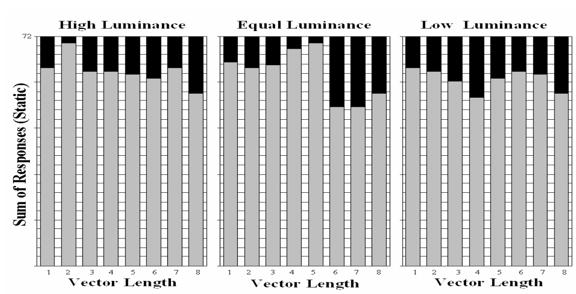


(a)

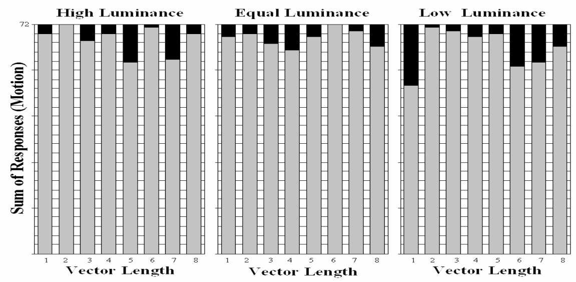


(b)

Figure 3. Results for translations (experiment 1): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli (grey bars represent 'Transparent' observers' responses, black bars represent 'Not Transparent' responses).

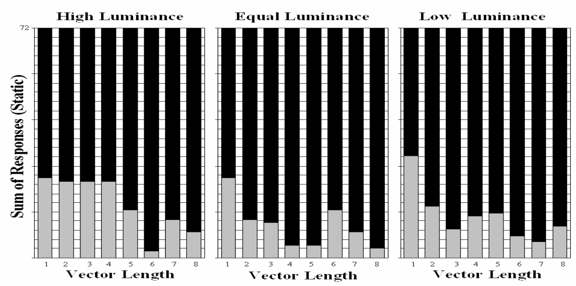


(a)

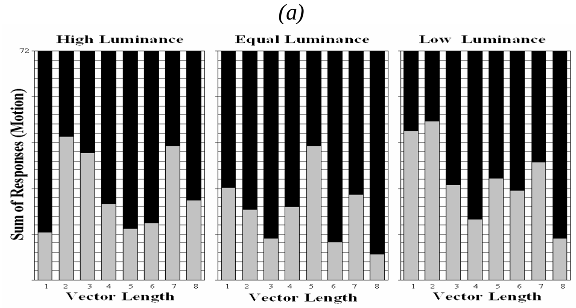


(b)

Figure 4. Results for convergences (experiment 1): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli.

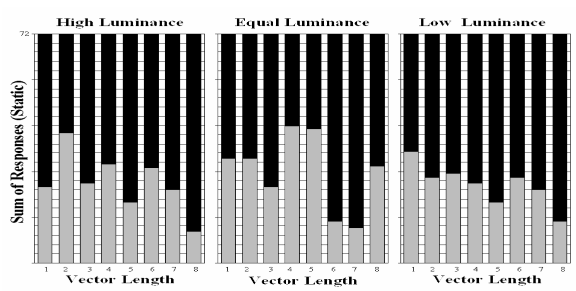


(a)

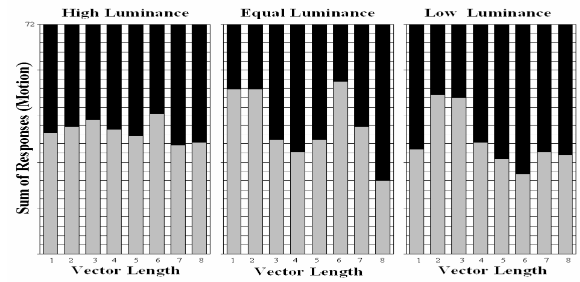


(b)

Figure 5. Results for shears (experiment 1): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli.



(a)



(b)

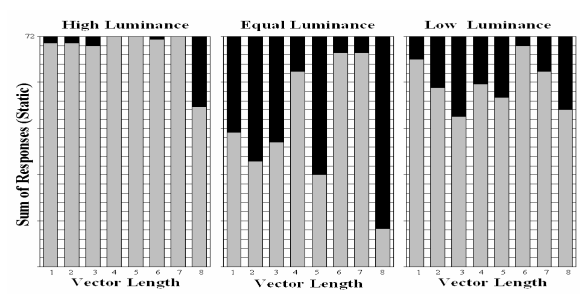
Figure 6. Results for divergences (experiment 1): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli.

For static stimuli, observers tend to see a transparent overlay for the illuminant condition with translations ($p<0.0001$), but not for equiluminant and filter conditions, where an effect of the vector length is noticeable. This effect is still perceived in equiluminant and low luminance conditions, but observers tend to respond 'Transparent' when the overlay moves ($p<0.0001$ and $p<0.05$ respectively). Observers tend to respond more frequently 'Transparent' for smaller norms of transformations in equiluminant and filter conditions. The difference between static and motion conditions is significant ($p<0.0001$) for the three luminance categories.

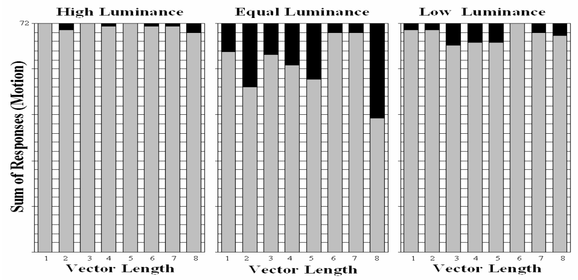
A relative effect of motion is perceived for convergences ($p<0.05$) for all luminance or vector lengths variations. An effect of motion is also seen for shears ($p<0.01$) as well as for divergences ($p<0.05$) in all luminance conditions, but responses still tend to 'Not Transparent'.

Experiment 2: Checkerboard like stimuli

Figures 7-10 summarize the responses of the observers for translations, convergences, shears and divergences for the checkerboard configuration experiment. The three plots present the cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static stimuli (a). The same configuration is presented for motion stimuli results in Figures 7-10 (b).

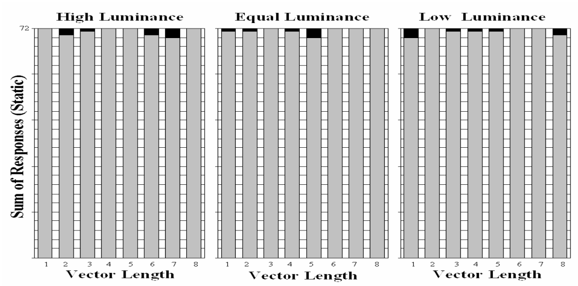


(a)

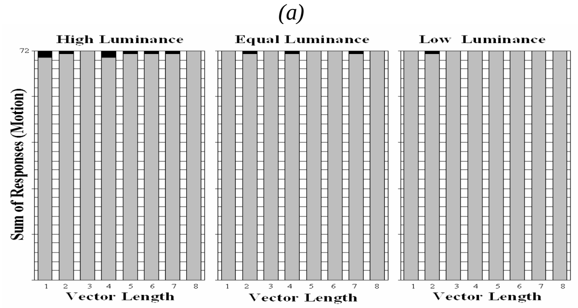


(b)

Figure 7. Results for translations (experiment 2): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli (grey bars represent 'Transparent' observers' responses, black bars represent 'Not Transparent').

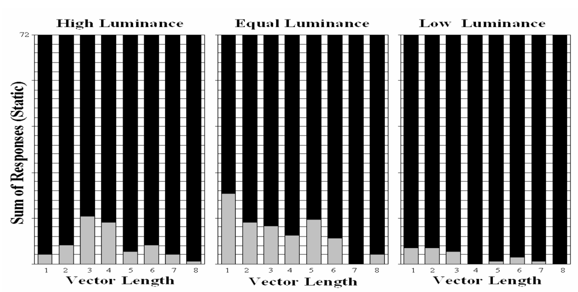


(a)

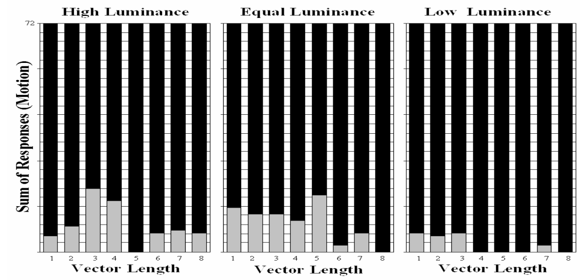


(b)

Figure 8. Results for convergences (experiment 2): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli.

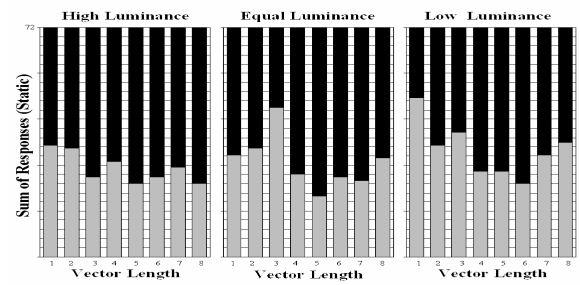


(a)

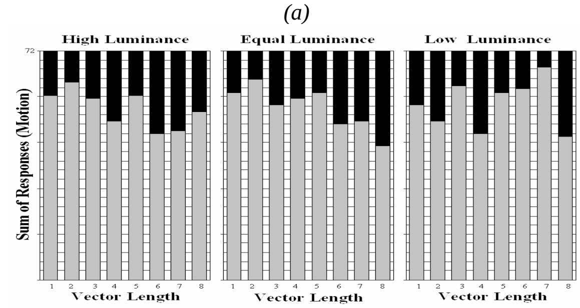


(b)

Figure 9. Results for shears (experiment 2): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli.



(a)



(b)

Figure 10. Results for divergences (experiment 2): cumulated responses for all subjects distributed as a function of vector lengths for illuminant, equiluminant and filter conditions for the static (a) and motion (b) stimuli.

For translations (Figure 7), the perception of transparency is enforced by the stimulus configuration and by motion ($p<0.0001$). No motion effect can be found for convergences since observers' responses are mostly 'Transparent' in the static condition. Motion has no effect on shears for all luminance and vector length variations. For divergences, a checkerboard configuration increases observers' responses in the 'Transparent' category, but the effect is not statistically significant. However, subjects' responses tend significantly to 'Transparent' ($p<0.0001$) for motion condition (Figure 10 (b)).

Discussion

In the first experiment, some translation stimuli tend to be perceived 'Transparent' when motion is added. For shears and divergences, the motion increases the number of 'Transparent' responses. Motion has a small effect on convergences when stimuli have simple configurations. Luminance levels and vector lengths have no significant influence, except for translations, and their effects subsist when the overlay moves. However, in the second experiment, these effects tend to disappear and the transparency perception is significantly increased for translations with checkerboard like stimuli, and moreover in the motion condition.

Convergences are the stronger chromatic change that leads to the perception of transparency: almost all presented checkerboard-like stimuli are seen as 'Transparent' when more surfaces are added. Motion has no effect on these convergences.

Surprisingly, divergences are perceived significantly transparent under checkerboard condition in motion. When static, observers have a doubt about transparency that decreases when motion is added. However, shears tend to be perceived opaque for a complex static or motion stimulus.

This raises the question about the saliency of transparency: in the case of checkerboard, forced-choice may not be the best procedure, and we are currently collecting data with different answer choices for the transparency level of the stimulus.

Conclusion

These experiments focused on the intensity, color relations, configuration type and motion parameters that are required for transparency to be perceived. According to our results, motion and the configuration complexity are both factors that enhance the perception of transparency for translations and divergences. However, motion has no effect on checkerboard convergences: the complexity of this configuration already influences observers to respond with high majority 'Transparent'. Interestingly, the inverse effect is observed for shears: the more patches are displayed, more often responses tend to be 'Not Transparent' even with motion added. The results for translations, convergences and divergences confirm those of Ripamonti et al. [8] who showed that the larger the number of surfaces in the stimulus, the stronger the impression of transparency is. However, we found contradictory results for shears compared to Hupé et al. [6].

Acknowledgment

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Biography

Peggy Gerardin received her D.E.A. degree in Cognitive Science from the University of Lyon, France in 2000. Since 2001, she's a Ph. D. student in the Laboratory of Audio-Visual Communications at the Ecole Polytechnique Fédérale de Lausanne, Switzerland. Her work is primarily focused on color vision and its application to color image processing. She's a member of IS&T.