Conspicuity in Terms of Peripheral Visual Detection and Recognition of Fluorescent Color Targets Versus Nonfluorescent Color Targets Against Different Backgrounds in Daytime

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A daytime field study was conducted to determine the conspicuity in terms of peripheral visual detection and recognition of different fluorescent and nonfluorescent color targets against different backgrounds. Ten color targets (6 × 12 in.), of which six were nonfluorescent and four were fluorescent, were tested against different nonuniform multicolored backgrounds. Three different painted plywood boards of 4 × 4 ft depicting either typical city, fall foliage, or spring foliage background colors were used as the backgrounds. The stimuli (color targets) were presented at three different peripheral angles (20, 30, and 40 degrees to the right of the line of sight) against the different backgrounds. Twelve subjects with normal color vision between the ages of 20 and 22 years participated in the experiment, which was conducted on an unused airport runway. A randomized block experimental design was used in such a way that for each subject the order of presentation of the three peripheral angles was random so that each angle occurred exactly once. Furthermore, for a given angle the order of presentation for the backgrounds was randomized so that each background occurred exactly once. For each background and for each of the two blocks of 10 colors each color was randomized in such a way that each color target appeared exactly once in the first block as Replication 1 and exactly once in the second block as Replication 2. Daytime chromaticity measurements were recorded for all of the color targets and background colors along with daytime luminance measurements of all of the color targets and backgrounds. The data were analyzed for two conditions: (a) detection percentage of total responses on the basis of the total number of presentations in which the subject detected the presence of a color target but in which the subject's color recognition response could be either the correct color or an incorrect color and (b) recognition percentage of the correct color target recognitions on the basis of the total number of presentations in which a subject's response with regard to the recognition of the color of the target was correct. In general, fluorescent yellow was found to be best detected and fluorescent orange was found to be best recognized against any of the three backgrounds investigated. Looking at the results of the study and the increased detection and recognition performances achieved with fluorescent colors for the conditions investigated, one may tentatively conclude that the fluorescent colors investigated in the study are considerably more conspicuous during daytime in terms of the peripheral detection and recognition percentages. It is recommended that designers of traffic signs, personal conspicuity enhancement items and devices, and roadside traffic control devices consider the superior visual conspicuity properties of fluorescent colors (especially fluorescent yellow and fluorescent orange) and incorporate them in designs when the highest possible daytime target conspicuity is absolutely necessary.

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The conspicuity of a target in the visual field can be indirectly measured by using a number of different experimental methods and measurements. For example, one can measure the detection distance and the recognition distance (*1*) or the reaction time for foveal or near-foveal target locations, or one can measure the detection or recognition percentages for peripheral target locations under certain experimental conditions (target size, exposure time, driver mental load, etc.). Usually, longer detection or recognition distances (foveal or near-foveal), higher peripheral detection or recognition percentages, and lower reaction times for target detection or recognition are assumed to correlate highly with higher conspicuities. In the context of this paper conspicuity is defined as an attention-getting ability or becoming aware of a new stimulus in the visual field almost instantaneously after the stimulus becomes present without any great visual search effort on the part of the observer. In the present study the peripheral detection and recognition percentages were used to measure the conspicuities of fluorescent and nonfluorescent color targets against different multicolored nonuniform backgrounds.

During the last decade several new aspects of peripheral vision have been studied and discussed. Zwahlen (*2–6*) provides evidence about the peripheral nature of the appearance of targets in a driver's visual field, peripheral detection performance as well as data on the fixation distributions and scanning behaviors of a driver's eyes. Looking at a driver's typical eye scanning behavior and noting that a driver makes a continuous string of discrete eye fixations (most eye fixations last between 0.1 and 0.8 sec; a few last up to 2 sec) ahead of the car, the selection of the peripheral detection and recognition percentages (suprathreshold conditions) as indirect measures of conspicuity would seem fairly appropriate within the traffic safety context. As a case in point it is very unlikely that a location in the driving scene at which the target becomes visible to a driver for the first time will coincide with the location in the driving scene where a driver is momentarily fixating his or her eyes. Wootan and Wald (*7*) reported on the detection of three colors for eccentricities of up to 80 degrees and concluded that people who cannot see colors in the periphery are not color blind and that this inability is caused by some element of the neural pathways rather than the failure of the color receptors. Noorlander et al. (*8*) compared peripheral stimuli with foveal stimuli and found that the spectrum loci are about 10 to 50 degrees away from the target under dark-adapted conditions and that there is a progressive contraction of the periph-

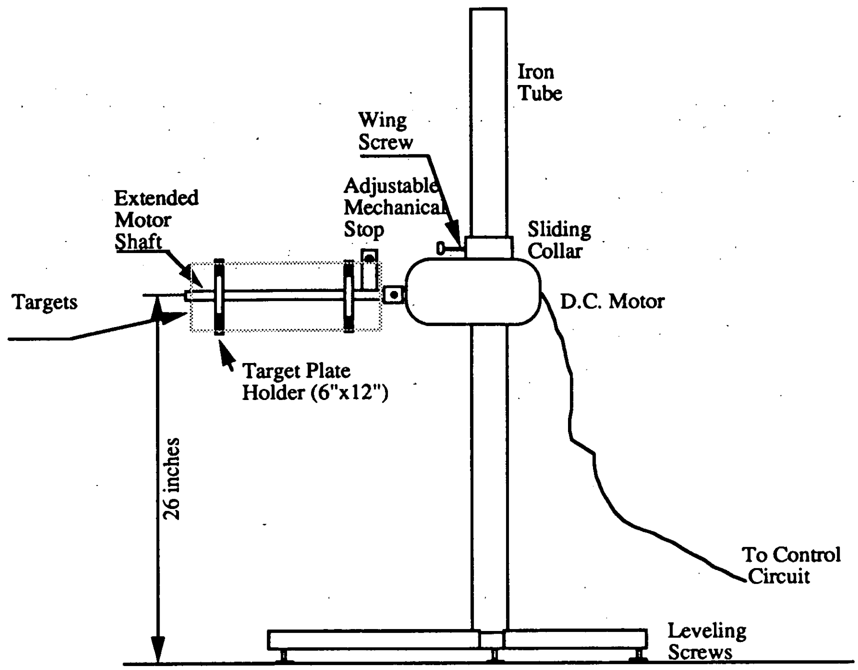

FIGURE 1 Target plate stand.

eral color with an increase in the distance from the fovea. Early evidence for a normal range of peripheral color vision was provided by Birch and Wright (*9*), who indicate that if the stimulus fields are increased in size a full range of hues could be seen in the periphery. It is also known from the studies of Stabell and Stabell (*10,11*) that for small stimulus fields foveal and peripheral color discriminations differ in their relative sensitivities according to different wavelengths. Moreover, Gordan and Abramov (*12*) provide evidence that various white fields differing in their chromaticities (which have been traditionally used for backgrounds) give results that are far better than those of backgrounds other than white. As cited earlier, Hanson and Dickson (*1*) conducted a study to establish the significant visual properties of some fluorescent pigments. Detection and recognition distances (at near threshold conditions) for six 0.01-ft^2-diameter circular color targets (two fluorescent and four conventional colors) displayed against three different background colors have been established. The study indicated a significant superiority of fluorescent colors when compared with the corresponding conventional colors, with the fluorescent yellow-orange target being the best detected and recognized target under all test conditions, and the authors concluded that where high target visibility is the primary objective the use of fluorescent pigments should be given serious consideration. In general, it can be observed from the available literature that peripheral detection or recognition of color targets decreases with an increase in the peripheral angle and that an increase in the target size (with an increase in the peripheral angle) would accommodate for fairly consistent color recognition in the periphery. However, none of the studies mentioned earlier investigated the peripheral detection and recognition of color targets presented against different backgrounds within a driving context. Therefore, the object of the study described here was to provide peripheral detection and recognition performances for fluorescent and nonfluorescent color targets against different nonuniform multicolored backgrounds to aid highway sign and other traffic control device designers in designing such signs and devices in a most appropriate and adequate manner for situations in which a high conspicuity performance during daytime is absolutely necessary and required.

METHOD

Subjects

Twelve subjects (six males and six females) between the ages of 20 and 22 years participated in the study. All the subjects had a valid driver's license with an average driving experience of 3 years. None of the subjects had any past accident history, although a few of them had moving traffic violations. The visions of all of the subjects were tested with a Baush and Lomb vision tester. They all had visual acuities ranging from 20/18 to 20/22 and normal contrast sensitivity as determined with Vistech contrast sensitivity charts.

Experimental Site and Apparatus

The study was conducted on an old unused airport runway (75 ft wide and 1,500 ft long) located on the outskirts of Athens, Ohio. The experiment was always conducted between 2:30 and 4:30 p.m., when direct sunlight was incident on the targets, using a 1979 Toyota Tercel as the experimental car. Six nonfluorescent and four fluorescent color targets (a total of 10 color targets of 6 × 12 in. in size) were used as stimuli in the experiment. Three different plywood boards of 4 × 4 ft depicting typical city colors (63.5 percent grey background with 36.5 percent red small irregular polygons), typical fall foliage (58.4 percent brown background with 17.4 percent yellow, 7.2 percent red, 9.6 percent green, and 7.5 percent grey

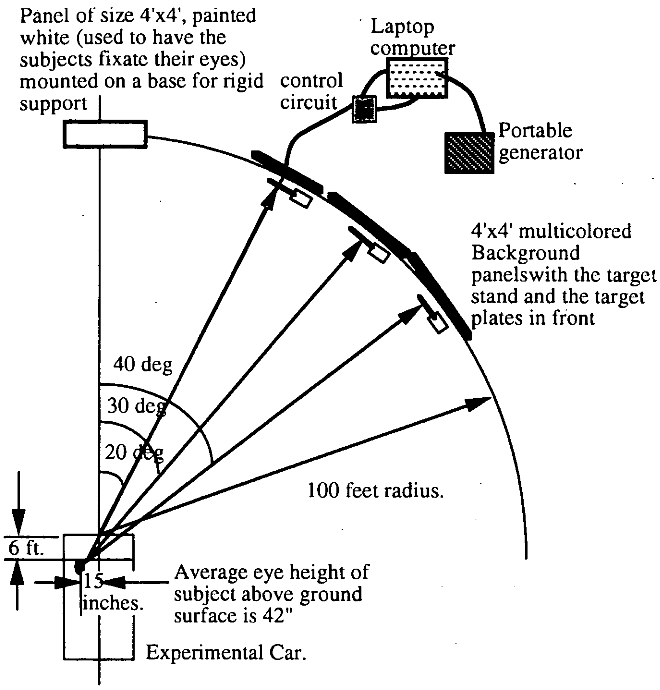

FIGURE 2 Experimental layout.

small irregular polygons), and a typical spring foliage colors (57.6 percent green background with 8.1 percent grey and 34.37 percent brown small irregular polygons) were used as backgrounds while presenting the targets to the subjects. A wooden base with two angle brackets fixed adjacent to each other was used to hold the background plywood boards in a vertical position.

TABLE 2 Average Luminances for Targets and Backgrounds

Target	Material	Average Luminance in cd/m^^2
City Background	Paint on Plywood	1592
Spring Background	Paint on Plywood	1410
Fall Background	Paint on Plywood	1617
Red	Retroreflective	1011
Blue	Retroreflective	845
Orange	Retroreflective	1530
Fluorescent Orange	Retroreflective	2247
Fluorescent Pink	Regular	2425
Fluorescent Orange	Regular	2134
Green	Retroreflective	872
Yellow	Retroreflective	2054
White	Retroreflective	2751
Fluorescent Yellow	Regular	4276

A white screen was placed straight ahead (along the longitudinal axis of the car) at a distance of 100 ft from the experimental car so that the subject seated in the car could easily fixate his or her eyes on the screen to avoid movement and fixations of the eyes toward the peripheral location of the targets. A computer-controlled portable black stand (to rotate the targets along the horizontal axis into an exposed position and to rotate them back into a nonexposed position) was used to mount the color target plates. The stand consisted of an adjustable base, a 4-ft-long adjustable iron tube, and a sliding collar that could be slid onto the tube and tightened at any selected height above the runway surface. A direct current motor was fixed at one side of the sliding collar, and the shaft of the motor

TABLE 1 Chromaticity Coordinates (2 degrees, D65 illuminant) for All Color Targets and Background Colors

Target	Material		Chromaticity Coordinates		
			x	y	Y
City Background	Paint on Plywood	Ash Grey	0.3063	0.3263	17.5500
		Cherry Red	0.4939	0.3209	7.4300
Spring Background	Paint on Plywood	Forest Green	0.3071	0.4151	7.2700
		Ash Grey	0.3063	0.3263	17.5500
		Leather Brown	0.4131	0.3724	4.8400
Fall Background	Paint on Plywood	Leather Brown	0.4131	0.3724	4.8400
		Lemon Yellow	0.4109	0.4452	65.3200
		Cherry Red	0.4939	0.3209	7.4300
		Forrest Green	0.3071	0.4151	7.2700
		Ash Grey	0.3063	0.3263	17.5500
Red	Retroreflective				
Blue	Retroreflective		0.1509	0.1344	2.6200
Orange	Retroreflective		0.6171	0.3803	15.2100
Fluorescent Orange	Retroreflective		0.6552	0.3407	39.7600
Fluorescent Pink	Regular		0.4345	0.2575	50.0200
Fluorescent Orange	Regular		0.6214	0.3722	33.8300
Green	Retroreflective		0.1247	0.4195	5.8600
Yellow	Retroreflective		0.5300	0.4606	30.2500
White	Retroreflective		0.3180	0.3359	48.4700
Fluorescent Yellow	Regular		0.4144	0.5484	109.7000

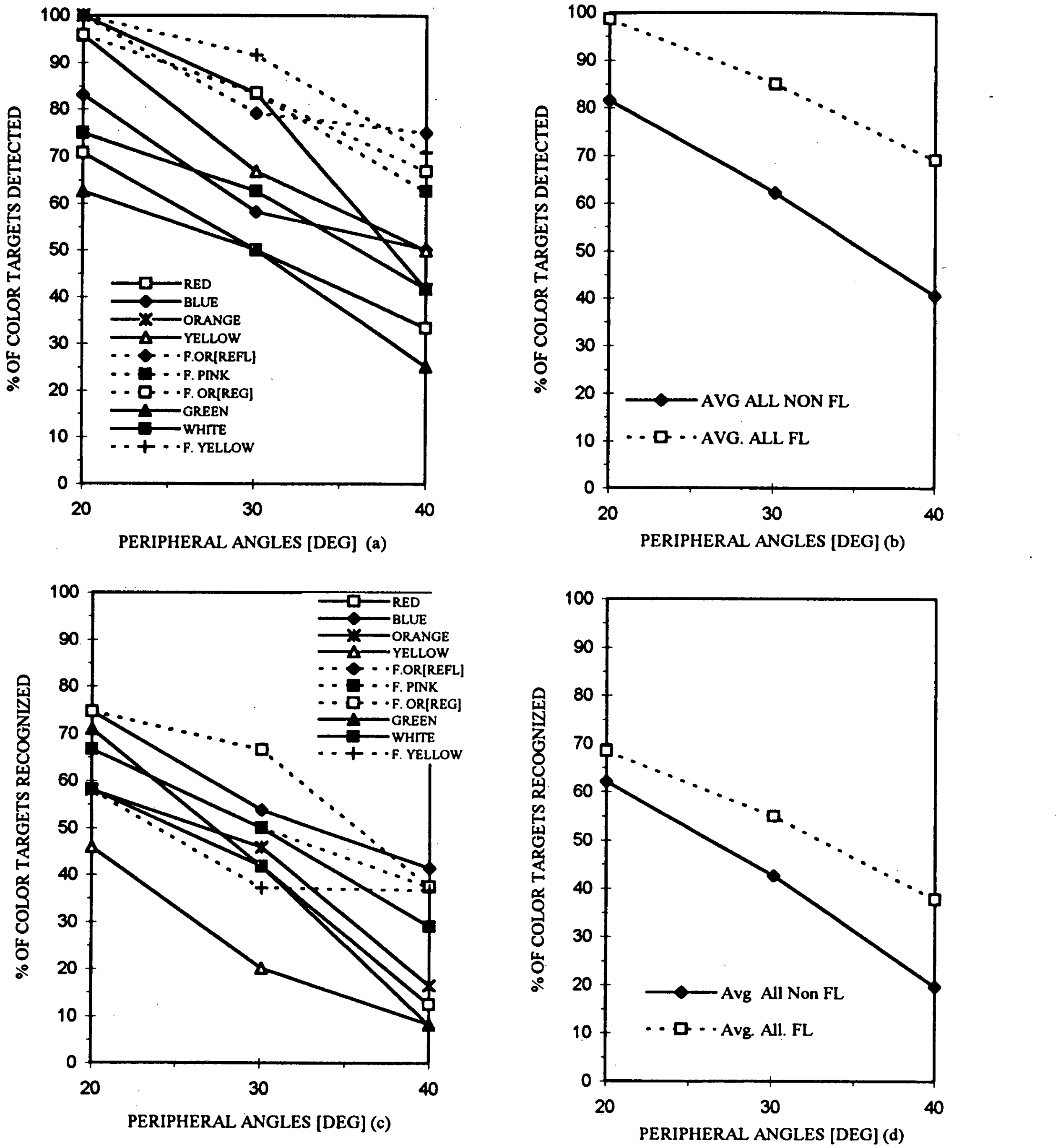

FIGURE 3 Percentage of color targets detected and recognized as function of peripheral angles against multicolored city background (grey with red designs): (*a*) percentage of color targets detected for all 10 colors, (*b*) percentage of color targets detected for average of all fluorescent colors ($n = 4$) and all nonfluorescent colors ($n = 6$), (*c*) percentage of color targets recognized for all 10 colors, and (*d*) percentage of color targets recognized for average of all fluorescent colors ($n = 4$) and all nonfluorescent colors ($n = 6$) (12 subjects, two replications; $n = 24$).

was extended to fit the bracket, which was capable of holding the targets rigidly. A diagram of the target-holding apparatus is shown in Figure 1. An electronic circuit was built to control the motor via a computer. A computer program (written in C language) for a Zenith laptop 8088 personal computer allowed the experimenters to rotate the target plate into view for a fixed amount of time (2 sec) specified by the computer program. The computer and the control circuit were powered by a portable generator. Walkie-talkies were used as communication devices between experimenters sitting in the car recording the responses of the subject and the experimenters operating the computer and changing the targets. Figure 2 shows a diagram of the experimental site and setup.

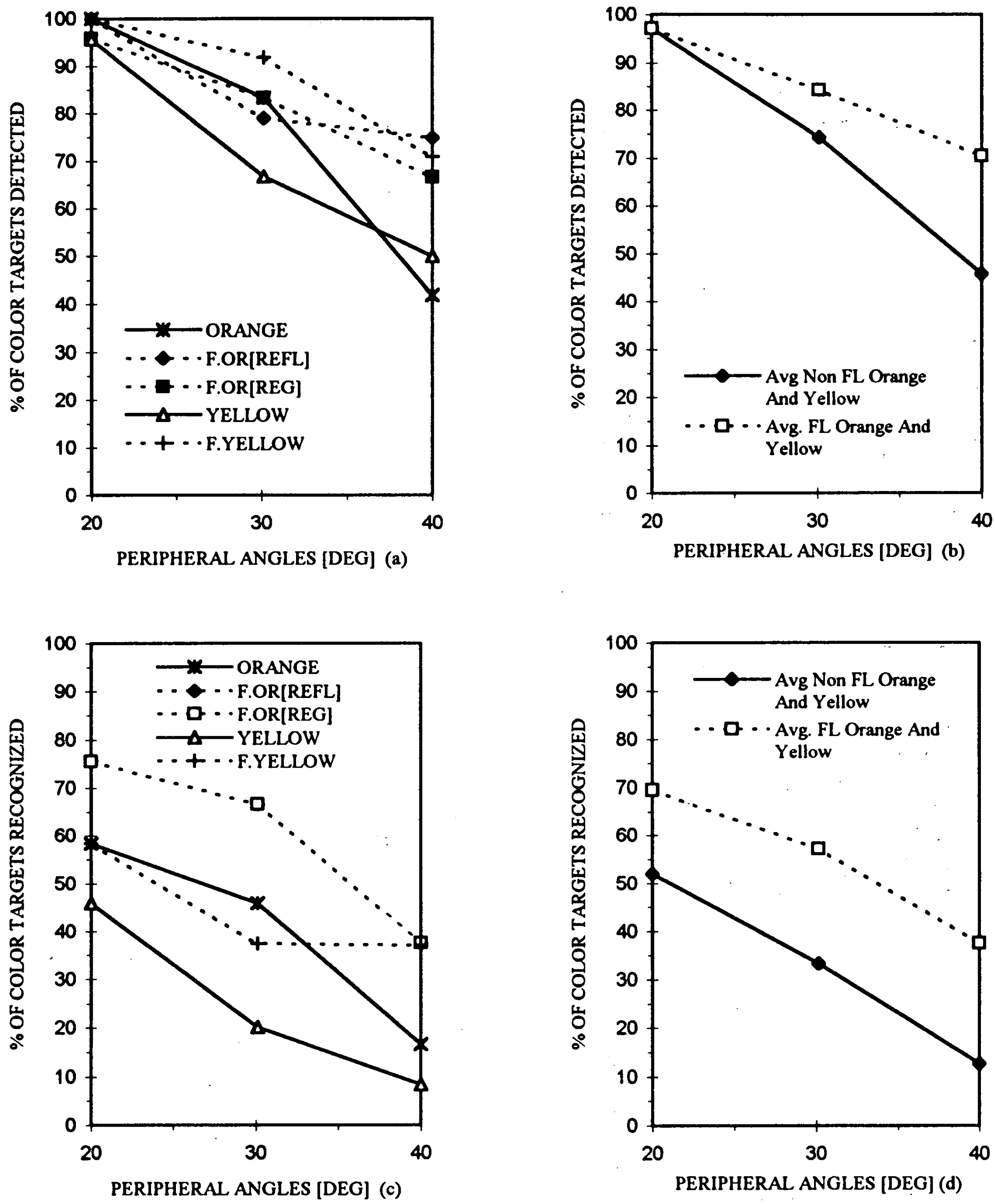

FIGURE 4 Percentage of color targets detected and recognized as function of peripheral angles against multicolored city background (grey with red designs): (*a*) percentage of color targets detected for fluorescent orange and yellow and nonfluorescent orange and yellow color groups, (*b*) average percentage of color targets detected for fluorescent orange and yellow (n = 3) and nonfluorescent orange and yellow (n = 2), (*c*) percentage of color targets recognized for fluorescent orange and yellow and nonfluorescent orange and yellow color groups, (*d*) average percentage of color targets recognized for fluorescent orange and yellow (n = 3) and nonfluorescent orange and yellow (n = 2) (12 subjects, two replications; n = 24).

Specimen Color Targets

The targets used in the daytime experiment were plates (6 × 12 in.) of retroreflective red, retroreflective blue, retroreflective fluorescent orange, retroreflective green, retroreflective orange, retroreflective white, retroreflective yellow, and regular fluorescent orange, regular fluorescent yellow, and regular fluorescent pink. Whether a color target was retroreflective or not was really of no consequence for this daytime experiment. Daytime luminance measurements were made for the three nonuniform multicolored background plywood boards depicting the different background scenarios and the different color targets by using the CapCalc computer-controlled luminance mea-

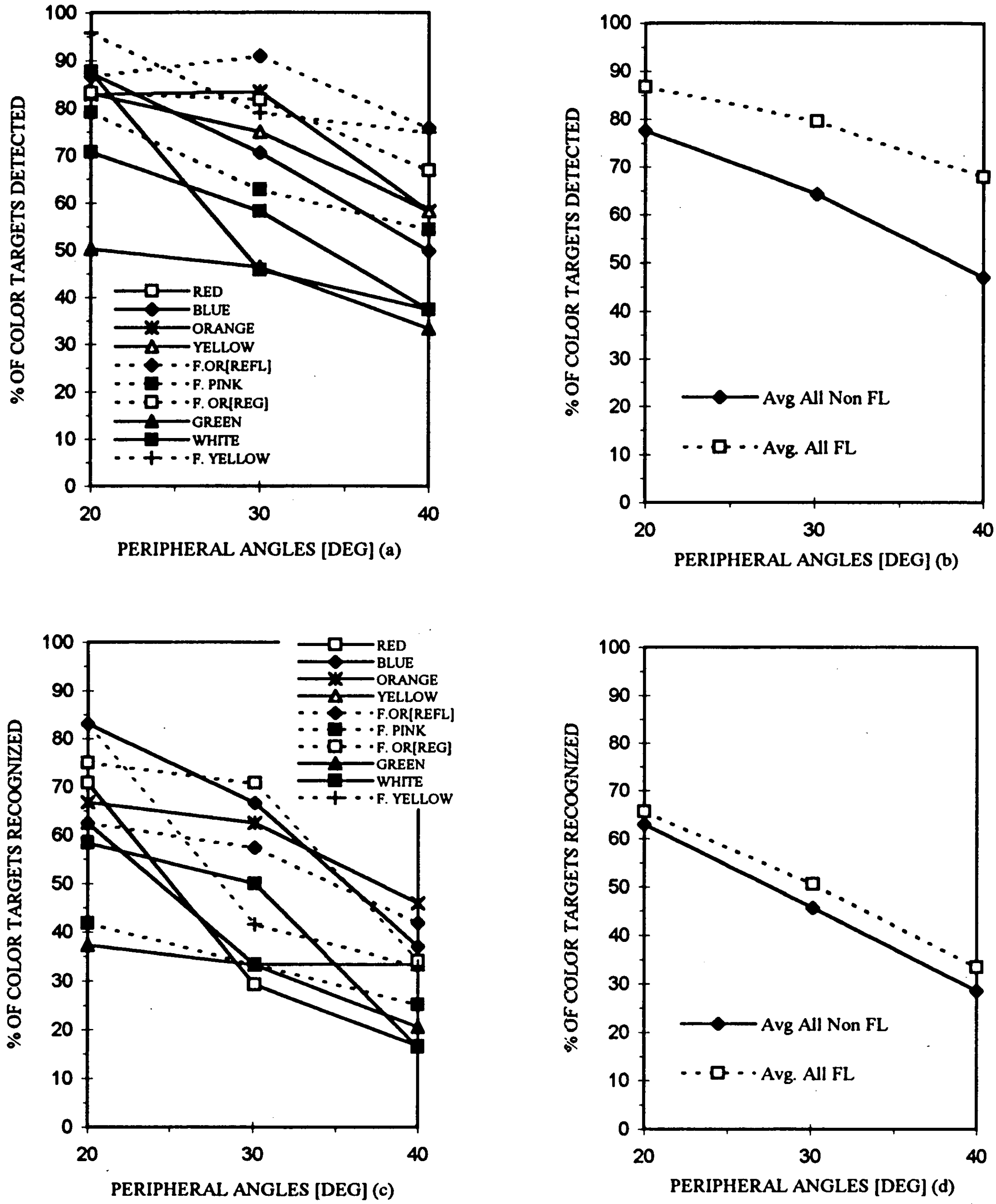

FIGURE 5 Percentage of color targets detected and recognized as function of peripheral angles against multicolored fall background (brown with red, yellow, green, and grey designs) (see legend to Figure 3 for descriptions of panels) (12 subjects, two replications; n = 24).

surement system from a distance of 100 ft under direct sunlight conditions. A description of the operation and features of the CapCalc system was given by Zwahlen et al. (*13*). Table 1 lists the daytime color chromaticity coordinates (2 degrees, D65 illuminant) for each color target and for each background color, and Table 2 lists the daytime luminance values of the color targets and the backgrounds.

Experimental Design

A randomized block experimental design was used in the experiment. The dependent variable was the subject's target detection and target color recognition response, and the independent variables were the 10 colors (retroreflective red, retroreflective blue, retroreflective fluorescent orange, retroreflective green, retroreflective orange, retroreflective white, retroreflective yellow, regular fluorescent orange, regular fluorescent yellow, and regular fluorescent pink), the peripheral angles at which the targets were displayed (three levels; 20, 30, and 40 degrees to the right of the line of sight), and the nonuniform multicolored backgrounds (three levels; city, fall, and spring foliage scenarios). The randomization for each subject was carried out by the following method. (a) The order of presentation for the peripheral angles was randomized so that each peripheral angle occurred exactly once. (All three backgrounds for a given peripheral angle were presented one after the other, to make the experiment more efficient.) (b) The order of presentation for the three backgrounds was randomized so that each background was used exactly once (Block 2 immediately followed Block 1). (c) The 10 colors were randomized for each background so that within a block of 10 colors each color appeared exactly once. (d) For each background and peripheral angle each of the 10 colors was presented twice in two randomized blocks of 10 in which each color

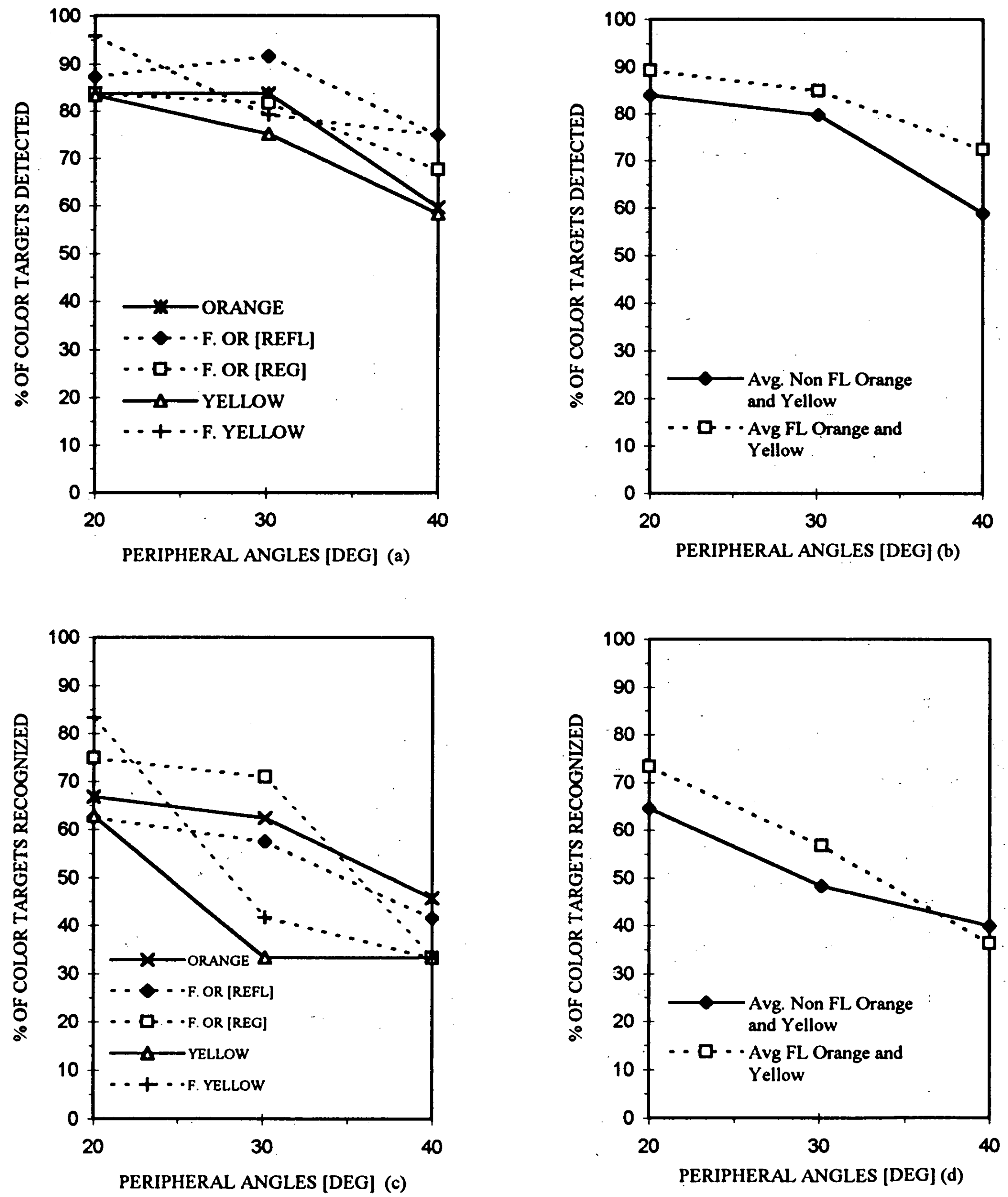

FIGURE 6 Percentage of color targets detected and recognized as function of peripheral angles against multicolored fall background (brown with red, yellow, green, and grey designs) (see legend to Figure 4 for descriptions of panels) (12 subjects, two replications; $n = 24$).

appeared exactly once. The random order was different for Block 1 and Block 2. The total number of presentations for each subject was 180 (three angles × three backgrounds × 10 colors × two replications).

Experimental Procedure

The subjects were given two trial runs after having received proper and detailed instructions about the procedure. Two experimenters sat in the car, one recorded the response of the subject, whereas the other was in constant communication with the experimenters at the target presentation stand and the computer via the walkie-talkies. Six experimenters were used to conduct the experiment, and it took each subject about 1.5 to 2 hr to go through the entire experiment. Vision testing and filling out a brief subject questionnaire took another 30 to 45 min. The subjects were seated in the driver's seat and were instructed to keep their eyes fixated on the white target screen placed at a distance of 100 ft directly in front of the car. The targets were displayed for 2 sec in front of a selected background in a ran-

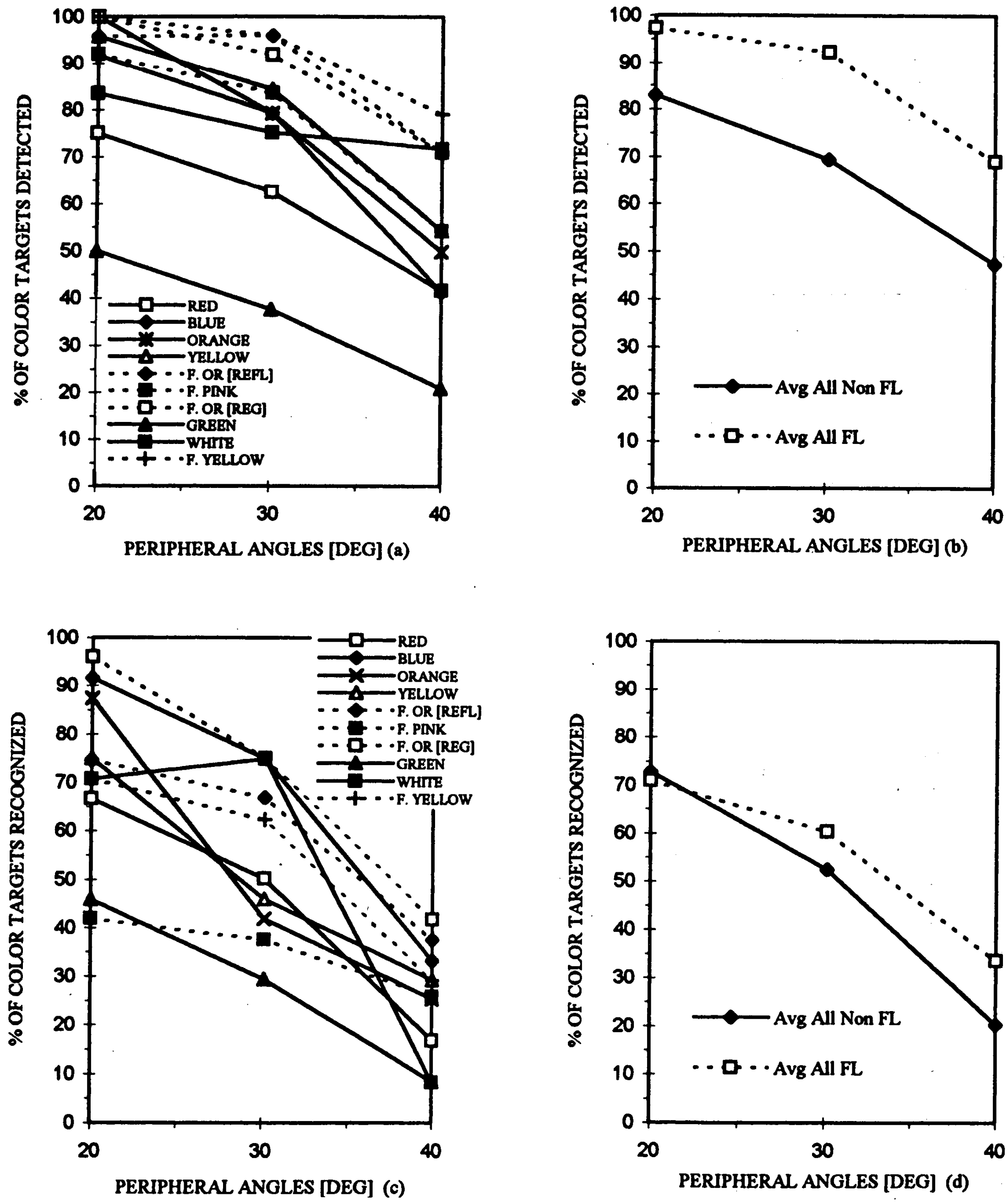

FIGURE 7 Percentage of color targets detected and recognized as function of peripheral angles against multicolored spring background (green with brown and grey designs) (see legend to Figure 3 for descriptions of panels) (12 subjects, two replications; n = 24).

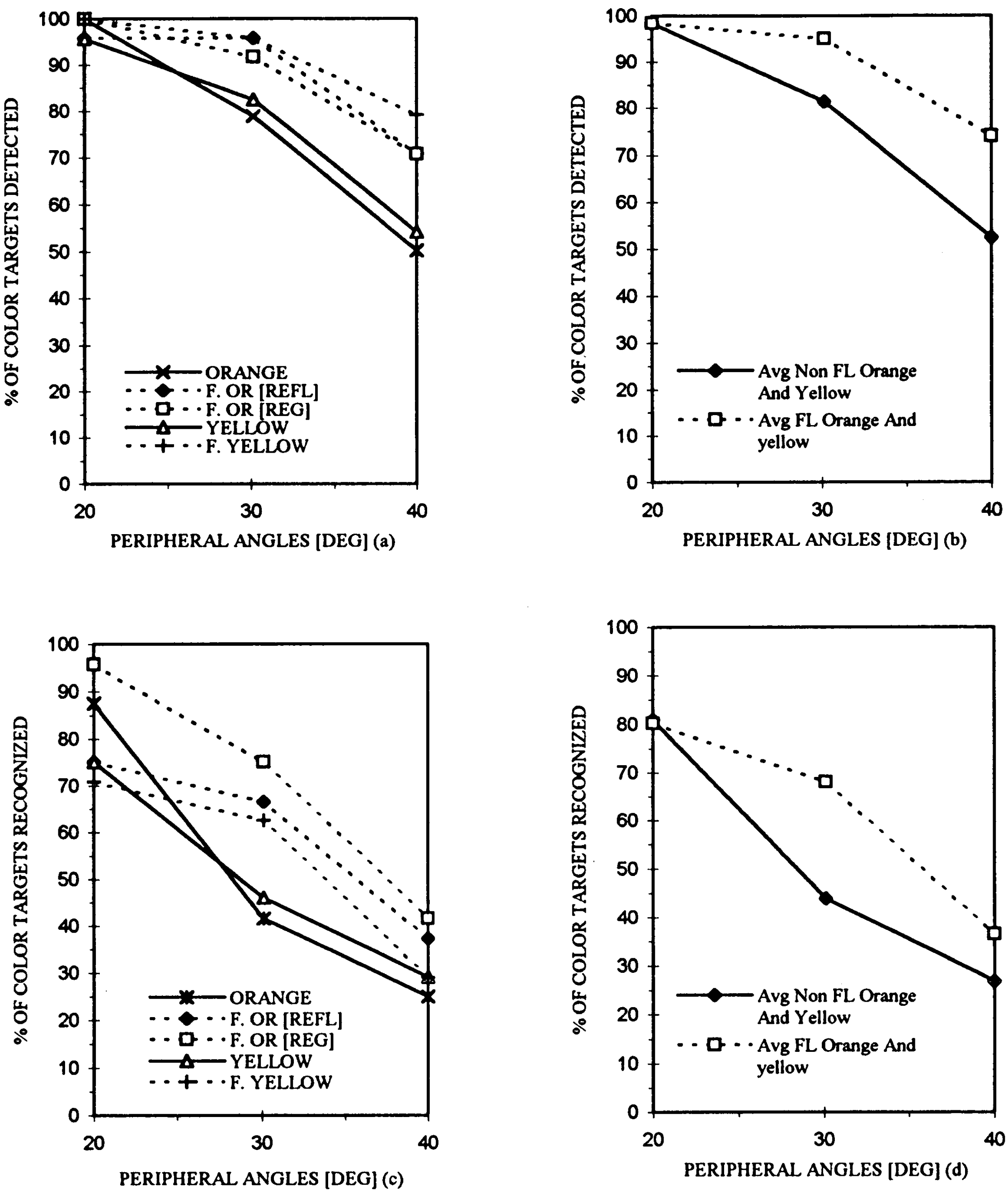

FIGURE 8 Percentage of color targets detected and recognized as function of peripheral angles against multicolored spring background (green with brown and grey designs (see legend to Figure 4 for descriptions of panels) (12 subjects, two replications; *n* = 24).

dom order as explained in the experimental design section. The target holder was fixed in such a way that the vertical center of the color target was at a height of 26 in. from the runway surface. Subjects were instructed to identify the color presented if they could recognize the color or say "blank" if they could detect a color target but could not discern any particular color. Regardless of the type of the color target displayed (fluorescent or nonfluorescent), the subject had to respond by just indicating a predetermined color name without having to decide wether or not the color was fluorescent or nonfluorescent. The response of a subject was noted down on the data collection form and was either one of the predetermined correct color names (red, blue, orange, yellow, green, pink or white), an incorrect predetermined color name (detection but not correct color recognition), or a blank (the color was not recognized). Two sets of data collection forms were prepared to test each subject, one for the experimenter noting down the responses of the subject in the car and the other one for the experimenters operating the computer and changing the targets. After the experiment was finished, an exit interview was conducted with each subject to find out if there were any difficulties during the experiment that could have affected the subject's performances in a detrimental way. The exit interviews indicated that none of the subjects had any problems of any sort during the experiment, and thus, all of the data collected for the subjects were used in the analysis.

RESULTS

An analysis of variance (at a 0.05 level) indicated that there was a significant effect with regard to detection and recognition when the background alone, the color alone, or the peripheral angle alone is considered. The data were analyzed for two conditions: (a) detection percentage of total responses based on the total number of presentations, in which the subject detected the presence of a color target but in which the subject's response could be either a correct or an incorrect color, and (b) recognition percentage of correct color target recognitions based on the total number of presentations, in which a subject's response with regard to the recognition of the color of the target was correct.

Figure 3 shows the percentage of color targets detected and recognized based on the total number of presentations for all 10 colors presented at the three different peripheral angles against the city background. Figure 3 (*a*) indicates that four fluorescent color targets usually had a higher percentage of detection when compared with those of the nonfluorescent color targets and that nonfluorescent orange had the highest percentage of detection among all six nonfluorescent color targets at lower peripheral angles (20 and 30 degrees). Figure 3 (*b*) indicates that the average percentage of fluorescent colors detected was higher when compared with the average percentage of the nonfluorescent colors detected at all peripheral angles (20, 30, and 40 degrees). Figure 3 (*c*) indicates the percentage of colors correctly recognized on the basis of the same conditions, and Figure 3 (*d*) indicates that the average percentage of recognition for all the fluorescent colors was higher than that for all nonfluorescent colors. Figures 3 (*a*) and 3 (*c*) indicate that both the regular and the retroreflective fluorescent orange colors had the highest percentages of detection (100 percent) and recognition (about 75 percent), respectively, at the lower peripheral angle of 20 degrees

TABLE 3 Group Averages and Standard Deviations for Percentages of Color Targets Detected on the Basis of Total Number of Color Target Presentations

Color Type	City Background			Fall Background			Spring Background		
	20 deg	30 deg	40 deg	20 deg	30 deg	40 deg	20 deg	30 deg	40 deg
All (Four) Fluorescent color targets	Retroreflective Orange, Regular Orange, Regular Pink, Regular Yellow.								
Group Average (N=12)	97.9	84.35	68.75	86.4	81.25	67.7	96.8	91.64	68.75
Group Standard-Deviation. (N=12)	2.42	5.25	5.37	7.10	13.82	9.88	3.9	5.89	10.5
All (Six) Non-Fluorescent color targets	Retroreflective Red, Retroreflective Blue, Retroreflective Yellow, Regular Orange, Retroreflective White, Retroreflective Green.								
Group Average (N=12)	81.23	61.79	40.3	77.07	59.71	45.83	82.62	70.13	50
Group Standard-Deviation (N=12)	14.60	12.47	9.7	14.67	21.5	11.17	18.33	17.95	23.43
Three Fluorescent Color targets	Retroreflective Orange, Regular Orange and Regular Yellow.								
Group Average (N=12)	98.6	84.71	70.83	88.86	87.5	72.22	98.6	94.4	73.60
Group Standard-Deviation(N=12)	2.42	6.37	4.16	6.36	7.22	4.809	2.42	2.3	4.80
Corresponding Non-Fluorescent Color targets	Retroreflective Yellow, Regular Orange,								
Group Average (N=12)	97.9	74.98	45.83	83.3	79.15	58.3	97.9	83.3	52.08
Group Standard-Deviation(N=12)	2.96	11.75	5.89	0.0	5.87	0.0	2.96	5.89	2.94

TABLE 4 Group Averages and Standard Deviations for Percentages of Color Targets Recognized on the Basis of Total Number of Color Target Presentations

Color Type	City Background			Fall Background			Spring Background		
	20 deg	30 deg	40 deg	20 deg	30 deg	40 deg	20 deg	30 deg	40 deg
All (Four) Fluorescent color targets	Retroreflective Orange, Regular Orange, Regular Pink and Regular Yellow								
Group Average (N=12)	68.75	55.21	37.37	65.62	50.83	33.33	78.83	60.41	33.33
Group Standard-Deviation. (N=12)	7.97	14.18	0.25	18.12	16.67	6.8	22.4	16.13	7.67
All (Six) Non-Fluorescent color targets	Retroreflective Red, Retroreflective Blue, Retroreflective Yellow, Regular Orange, Retroreflective White and Retroreflective Green								
Group Average (N=12)	62.49	42.23	19.45	63.18	45.8	28.47	72.9	52.7	20.13
Group Standard-Deviation (N=12)	10.55	11.89	13.35	15.23	16.24	12.19	16.40	18.57	10.67
Three Fluorescent Color targets	Retroreflective Orange, Regular Orange and Regular Yellow								
Group Average (N=12)	69.4	56.95	37.3	73.6	56.67	37.44	80.55	68.05	36.11
Group Standard-Deviation(N=12)	9.63	16.84	0.28	10.47	14.59	7.124	13.39	6.36	6.37
Corresponding Non-Fluorescent Color targets	Retroreflective Yellow and Regular Orange								
Group Average (N=12)	52.1	32.94	12.5	64.58	47.91	39.58	80.25	43.75	27.08
Group Standard-Deviation(N=12)	8.86	18.18	5.89	2.95	20.6	8.83	8.83	2.94	2.94

against the multicolored city background. The nonfluorescent orange target had about 58 percent recognition, whereas the two fluorescent orange targets had about 75 percent recognition at a peripheral angle of 20 degrees. Figure 4 (*a*) indicates that the percentage of color targets detected was higher for fluorescent orange and yellow than for the nonfluorescent colors. Also, Figure 4 (*b*) indicates that at the greater angle (40 degrees) the average percentage of detection was higher for fluorescent orange and yellow than for the nonfluorescent colors. Figure 4 (*c*) indicates that the percentage of color targets recognized for fluorescent yellow was higher at all three peripheral angles, and at 40 degrees the recognition was about 40 percent for fluorescent orange and fluorescent yellow, which is higher than that for nonfluorescent orange and yellow, and Figure 4 (*d*) indicates that the average percentage of recognition for fluorescent orange and yellow was much higher than the averages for nonfluorescent orange and yellow; this difference increases as the peripheral angle increases.

Figure 5 depicts the percentage of colors detected and recognized on the basis of the total number of color target presentations for all 10 colors presented at the three different peripheral angles against the multicolored fall foliage background. Figure 5 (*a*) indicates that fluorescent yellow had the highest percentage of detection (about 95 percent at a peripheral angle of 20 degrees and 80 percent at a peripheral angle of 40 degrees). Figure 5 (*c*) shows the percentage of color targets correctly recognized on the basis of the same conditions as detection. Figure 5 (*c*) indicates that fluorescent orange was best recognized (about 75 percent recognition) at a peripheral angle of 30 degrees and that nonfluorescent orange was best recognized at a peripheral angle of 40 degrees. Figure 5 (*b*) shows that the average percentage of detection of the targets for all fluorescent colors was about 86 percent, whereas it was 76 percent for all nonfluorescent colors. The difference between the percentage of detection of all fluorescent and nonfluorescent colors was about 10 percent at 20 degrees, and this difference increased as the peripheral angle increased (at 40 degrees the difference was 20 percent). Figure 5 (*d*) indicates that the average percentage of recognition for all fluorescent colors was still more than that for all nonfluorescent colors, but this difference was not very large. These figures indicate that the fluorescent color targets were easier and more successfully detected and recognized than the corresponding nonfluorescent color targets. Figure 6 (*a*) also indicates that fluorescent yellow was best detected at a peripheral angle of 20 degrees at 95 percent compared with 85 percent detection of nonfluorescent yellow against the multicolored fall background. Figure 6 (*b*) indicates that the average percentage of detection for fluorescent orange and yellow colors was higher than that for nonfluorescent orange and yellow colors at all three peripheral angles. Moreover, at the lower peripheral angle (20 degrees), fluorescent yellow had a higher percentage of recognition, and at 30 degrees the regular fluorescent orange had about 75 percent recognition [Figure 6 (*c*)]. At the higher peripheral angle (40 degrees), the nonfluorescent orange target had a higher percentage of recognition (about 55 percent) than regular fluorescent orange, which had about 35 percent recognition. At the lower peripheral angles (20 and 30 degrees), fluorescent orange and yellow were better recognized (about 75 and 60 percent recognition, respectively) than nonfluorescent orange and yellow (about 63 percent and 50 percent recognition, respectively) [Figure 6 (*d*)].

Figure 7 illustrates the percentage of targets detected and recognized on the basis of the total numbers of representations for all 10 color targets presented at the three different peripheral angles against the multicolored spring foliage background. Figure 7 (*a*) shows that regular fluorescent yellow was easier and better detected at all three peripheral angles (i.e., 100 percent detection at 20 degrees, 95 percent detection at 30 degrees, and 85 percent detection at 40 degrees) than all of the other nine colors. Figure 7 (*b*) indicates that the average percentage of detection for all fluorescent colors was higher than that for all nonfluorescent colors. But Figure 7 (*d*) indicates that the average percentage of recognition for all fluorescent colors was same as that for all nonfluorescent colors at a peripheral angle of 20 degrees. At higher peripheral angles, however, the fluorescent colors had better recognition than the nonfluorescent colors. Figure 7 (*c*) indicates that fluorescent orange (regular) was the best recognized at all three peripheral angles. Figure 8 (*a*) indicates that fluorescent yellow had the highest percentage of detection at all three peripheral angles, and Figure 8 (*c*) indicates that retroreflective fluorescent orange had 75 percent recognition, whereas regular fluorescent orange had 95 percent recognition at the lower peripheral angle of 20 degrees and about 48 percent recognition at the higher peripheral angle of 40 degrees. Figure 8 (*b*) indicates that the average percentages of detection for fluorescent or-

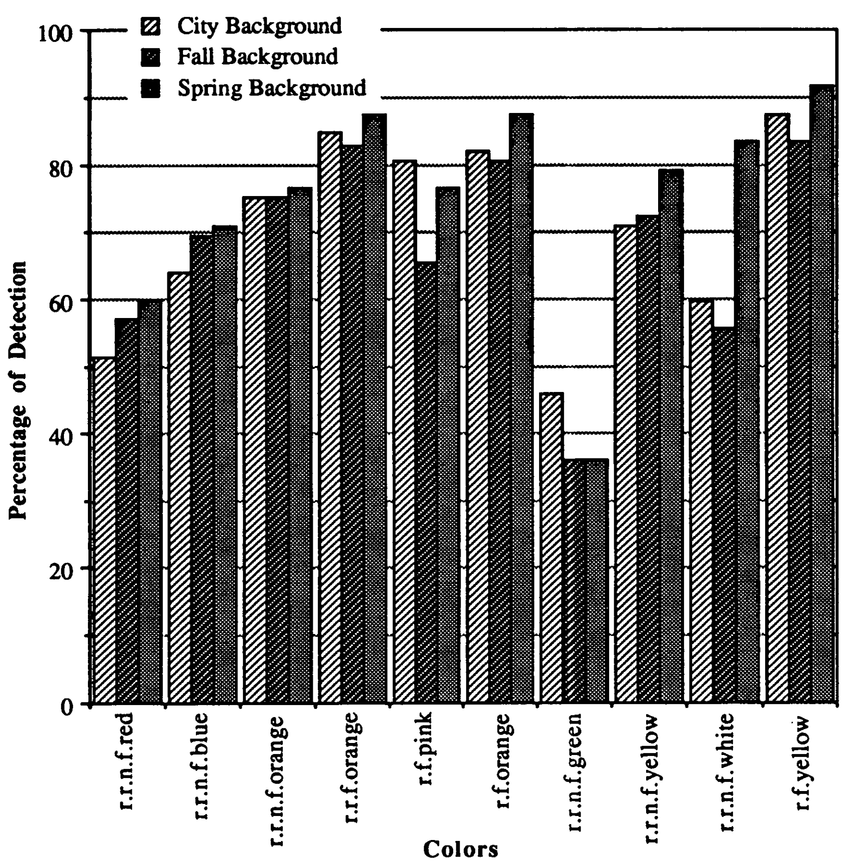

FIGURE 9 Comparison of percentage of targets detected for 10 colors against three backgrounds for all three peripheral angles combined (12 subjects, two replications; $n = 72$ per background). r.r.n.f. = retroreflective nonfluorescent; r.r.f. = retroreflective fluorescent; r.f. = regular fluorescent.

ange and yellow and nonfluorescent orange and yellow were the same at a peripheral angle of 20 degrees, but at a peripheral angle of 40 degrees the average percentages of detection for fluorescent orange and yellow were higher than those for nonfluorescent orange and yellow.

Tables 3 and 4 provide averages and standard deviations for the percentages of detection and recognition, respectively, for the combined data for all 12 subjects. Both tables indicate that the percent averages for the groups are almost always higher and that the percent standard deviations for the groups are almost always lower for the fluorescent color targets than for the nonfluorescent color targets. This superiority of the fluorescent color targets is maintained when a comparison is made between the fluorescent color targets and the corresponding nonfluorescent color targets, whose percent averages and standard deviations for the groups are also shown separately in the two tables. Figures 9 and 10 show the percentages of detection (averaged for all three peripheral angles) and the percentages of recognition (averaged for all three peripheral angles), respectively, for all the 10 color targets against all three multicolored backgrounds. It can be seen from Figure 9 that 8 of the 10 color targets used in the study were better detected against the spring background than against the city and fall foliage backgrounds. Similarly, Figure 10 shows that 7 of the 10 color targets were better recognized against the spring background than against the city and fall backgrounds.

CONCLUSIONS

The available literature on foveal and peripheral detection of color targets has been reviewed. Both studies have concluded that there is a significant difference between the foveal detection of fluorescent colors (easier and more successfully detected) and nonfluorescent colors. Based on the results of the study one can conclude that, in general, fluorescent color targets of 6 × 12 in. shown peripherally between 20 and 40 degrees to the right of the line of sight at a distance of 100 ft (target size is 17 × 34 min of visual arc) are more easily and more successfully detected and recognized than similar nonfluorescent color targets against the three different selected multicolored backgrounds used.

If one wants the highest peripheral detection performance against a city background, a fall foliage background, or a spring background, the best color is fluorescent yellow. If one wants the highest correct peripheral recognition performance against a city background, a fall foliage background, or a spring background, the best color is fluorescent orange. It is therefore recommended that

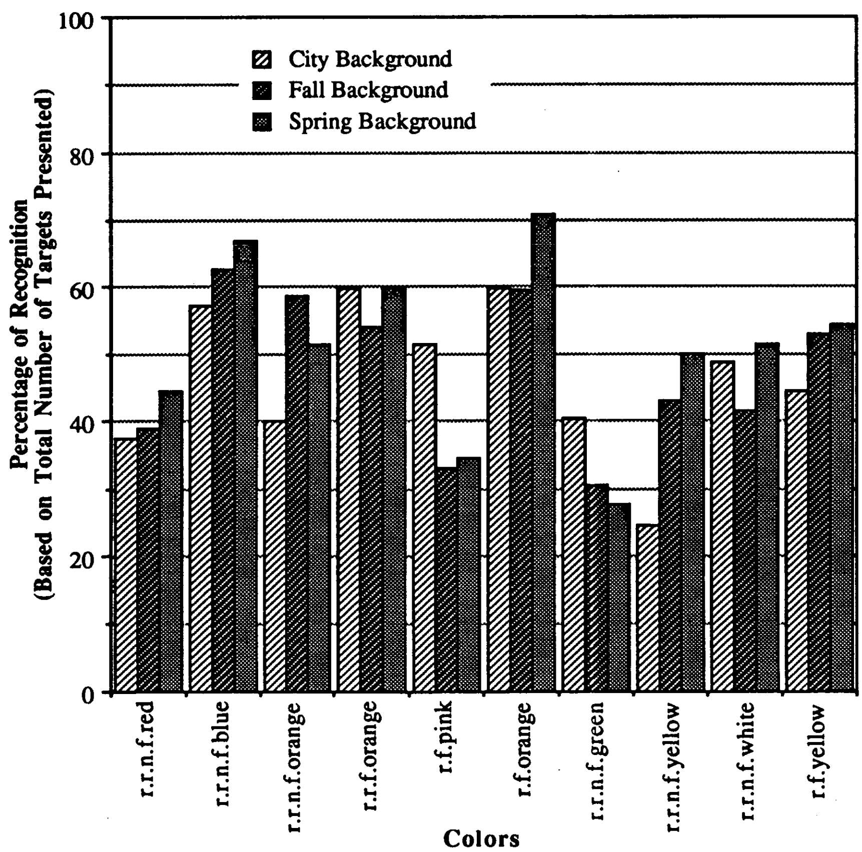

FIGURE 10 Comparison of percentage of targets recognized on the basis of total number presented for all 10 colors against three backgrounds for all three peripheral angles combined (12 subjects, two replications; $n = 72$ per background).

designers of traffic signs, personal and other daytime conspicuity enhancement items or devices, and roadside traffic control devices should consider the superior visual conspicuity properties of fluorescent colors (especially fluorescent yellow and fluorescent orange) and incorporate them in designs when the highest possible daytime target conspicuity is absolutely necessary and required. It should also be noted that the results obtained in the study and the conclusions drawn are based on the performance of young, healthy college-age subjects and with color targets of only 6 × 12 in. displayed peripherally at a distance of 100 ft. Additional research would be needed to generalize these results to other conditions in which target size, target area, peripheral angles, immediate background size and color composition, illumination condition, target exposure time, driver population, and mental loading level of the driver are much different from the conditions used in the present study.

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