Effect of Object Outline Color and Width on Visual Preferences of Young Children for PDA-based Learning Applications

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Abstract: In visual applications, the color and width of an object's outline determine the feelings invoked in the viewer. This study investigates the effect of the outline color and width on the preference of young children for objects presented in PDA-based learning applications. The impact of three different outline colors [the original object color, a darker color of the same hue and saturation as the original object color, and black] and three different outline widths [1 pixel, 2 pixels, and 4 pixels] on the visual preferences of young children is examined in a series of experiments conducted with kindergarten and elementary school students in Taiwan.
The analysis of variance results suggest that young children prefer the outline of the object to be the same color as the object itself or at most to have a thin frame with the same color as the original object, but with a slightly darker shade.

Key-Words: - **C**olor; Preference; Displays; Children; Graphic arts; Outline

1 Introduction

Small screen display interfaces are increasingly light and portable. User preferences in such devices are widely investigated in order to improve the user experience. Young children are the users of the future, and are interested in pattern design. Therefore, the effect of pattern design on user interfaces is an important issue. Therefore, the preference of young children for small screen display interfaces is an important research topic.

This study investigates the preferences of young children for pattern designs on small screen display interfaces. Most relevant research indicates that the application of screen interface displays is increasing. Therefore, consideration of user preferences could influence user behavior and enhance their interest. The preferences of children are particularly important, since children are the users of the future.

Accordingly, the research background and motivation of this study is divided into three fields, namely using a small screen as a display interface, issues relevant to user preferences, and the use of young children as users. Each focus of this study is explained below.

Young children in Taiwan (and indeed, throughout the world) are commonly taught new concepts using some form of image-based approach, such as flash cards[1], for example. Gustafsson[2] commented that learning new vocabulary items and developing counting skills are fundamental educational tasks. Previous studies have discussed the use of images in vocabulary learning.

Näsänen[3]suggested that in addition to graphical information, patterns play an important role in user interfaces.An item of visual communication design is proceeded in pattern design using applied cognitive psychology. Pattern design represents a picture language. Therefore, pattern designs would transfer the content. Communication of content using patterns relates to cognitive psychology.

Image-based learning approaches are used to teach many different classes of vocabulary item[4]. A common example is that of teaching the counting units ("one", "two", "three", etc.), in which each unit is typically accompanied by a corresponding number of objects. A review of the teaching materials used in kindergartens and elementary schools in Taiwan suggests that the object designs used in most current image-based learning approaches can be classified into one of three different types: (1) an unframed solid-rendered colored object, (2) a colored object with an outline rendered in a darker color of the same hue and saturation as the original object color, and (3) a colored object with a black outline. However, these teaching materials are generally designed by adults, who unconsciously impose their own subjective feelings and preferences when designing the color and width of the object outline. Therefore, the preferences and likely responses of the target audience (i.e. young children in the case of image-based teaching materials) are not considered. However, when designing teaching materials, it is essential that the particular interests and capabilities of the young learners are specifically taken into account such that their unique needs and preferences are more closely satisfied[5].

Isen[6] observed that people who feel better tend to in positive material more accessible tend to be more optimistic, tend to judge things to be better than usually. Moore[7] explored the preference procedure depended on the actual or imagined alternatives to make it possible to judge an option, more information was not necessarily better and that the order of information acquisition might influence the preferences for the available options. Chen[8] pointed that graphical interface layouts would be more acceptable for young children. So, the researchers focus on children preference.

The development of new technologies is having a tremendous impact [9],small screen display devices have found increasing use and favor in many aspects of our daily lives in recent years[10], ranging from cell phones, to handheld games consoles, to PDAs, and so forth. Certainly, a strong trend exists toward the development of technologies aimed at providing users with instant access to information on demand at any time and at any place. It seems certain that the screen-based method of information presentation will continue as a major trend for the foreseeable future.

Rapid scientific and technological advances in the computing field in recent years[11] ,E-learning represents the interaction between the teaching-learning process and the informational technologies[12]. Personal Digital Assistants (PDAs) have emerged as an increasingly popular tool for information storage and presentation purposes. PDAs offer many advantages in the learning environment[13], Segall[14] observed that personal digital assistants (PDAs) have been incorporated into assistant curricula in recent years in an attempt to enhance students' knowledge experience and reduce instructors' workload.With their light weight and compact dimensions, PDAs provide a convenient means of storing and presenting huge volumes of data. Simply by inserting the appropriate data cards, an entire collection of textbooks can be stored and presented on a single PDA device, thereby avoiding the need for children to carry large numbers of books. Furthermore, even young children tend to be familiar and comfortable with the use of electronic products nowadays, with the result that PDAs provide a less threatening and more stimulating learning interface than that provided by conventional paper-based textbooks. Accordingly, the present study investigates the use of a PDA as the learning interface for new Chinese vocabulary items using an object-based approach. Specifically, the study investigates the effects of the color and width of the object outline on the young children's visual preferences.

In our daily life colors are never seen in isolation, but always presented together with other colors[15].A review of the literature reveals that many studies have been conduced into the effects of color on the visual preferences of the viewer. Typically, such studies have focused on the effects of the object color itself and / or on the visual impact of different object outline styles, e.g. different colors or different widths. For example, a study into color brightness evaluation using colors involving participants in their late twenties[16]. Similarly, Camgöz[17] investigated the preference responses of a group of university undergraduates for different foreground-background color relationships, Shoyama investigated the color preferences for elderly people's clothing in Japan and Korea and examined the difference in color perception among elderly women and female students by displaying images on a computer screen and then using computer graphics to change the color of the clothing[18]. Camgöz[17] pointed out that preference is essentially a subjective response on the part of the viewer, combining such concepts as "like / dislike", "pleasantness to the eye", "visually appealing / unappealing", "attractive / unattractive", "suitable / unsuitable", and so on. In the studies presented above, the participants were all adults. Clearly, however, since preferences are subjective, the preferences of an older age group are unlikely to match exactly those of a younger audience. Accordingly, the present study chooses young children as the participants in the current experimental trials and investigates their particular set of color preferences.

This study uses a PDA as the presentation interface for teaching materials aimed at developing counting skills in young learners. Technological interfaces can appear to be cold and detached. Therefore, interface display design is a very important factor in producing applications. Consideration of user preferences, and a reasonable and suitable resolution of information, ensure effective communication. A simple communication model is important for the good presentation of an interface design. The aim of the study is to investigate the preferences of the young learners for the color and width of the object outline. The results of the study provide an objective reference for the design of image-based teaching materials which more closely match the particular visual preferences of young children and therefore enhance their learning motivation and performance.

However, the current study considers the case where images are used to develop and reinforce counting skills. In such applications, the visual aspects of the images have a direct effect on the children's receptiveness to the learning process. Since adults and children have different visual preferences, so research on interface design for adults does not suit children's requirements. These teaching materials are generally designed by adults, who impose their own subjective feelings and preferences when designing the brightness and width of object outlines. Therefore, the likely preferences of the target audience (i.e. children in the case of pattern-based teaching materials) are not considered. However, the importance of considering the particular interests and capabilities of children when designing teaching materials such that their own particular needs and preferences are closely satisfied. The study relates to children's visual preferences. Visual interfaces need to conform to children's visual preferences if they are to be used by children.

In a study addressing the impact of homogeneous backgrounds, Brown[19] pointed out that objects used in image-assisted learning tasks are generally presented against a white background, and hence using an outline color which is a lighter shade of the object color, but has the same hue and saturation, is visually confusing. Accordingly, in the present study, the outline color factor is assigned three levels, i.e. the original object color, a darker color with the same hue and saturation as the original object color, and black (see Table 1). The outline width factor is also assigned three levels, namely thin (1 pixel), medium (2 pixels), and thick (4 pixels).

Table 1 Experimental factors and their levels

	Level 1	Level 2	Level 3
Color	Original	Darker	Black
Outline	1 pixel	2 pixels	4 pixels

2 Experimental Procedure

2.1 Experimental Setup

Pattern design is an important factor human-machine interface design, particularly in graphical user interfaces. Multimedia Screen displays and traditional paper displays have different presentation issues. Therefore, the pattern effect on small screens is an important research topic. The experimental setup consisted of a PDA screen with all of the desktop patterns switched off. Adobe Photoshop was used to design the current image set (eight identical apples arranged in two horizontal rows of equal length) using the RGB (Red, Green and Blue) and HSB (Hue, Saturation and Brightness) color models. The images were saved in *.jpg files and displayed within a screen area measuring 320 x 240 pixels.

Ou[15]stated that in every aspect of daily life, colors are never seen in isolation, but are always present together with some other color. This is equally true whether observing a typical street scene or examining the teaching materials within a textbook aimed at young learners. Chang[20] pointed out that the format and appearance of teaching materials has a profound influence on their ability to engage the interest of young learners and to prompt their desire to study. Furthermore, Davidoff[21] reported that although verb labels should be acquired later than noun labels, young children would not necessarily have more difficulty naming pictures relating to verbs rather than pictures of nouns. Wang[22] indicated that presenting static information against a white background color resulted in a higher subject comprehension. Accordingly, the current images sets were all designed with two basic colors (red and green) and presented against a white background with a simple written instruction (in black) below the image.

Hernàndez[23] suggested that color provides a strong indication of the quality of a food product. As such, the food's color is of immediate interest and significance to the viewer. This study chose an apple as the test image since this particular fruit has distinct features, i.e. the body and the leaf, and can be expressed in easily recognizable form using just two colors, i.e. red and green. Furthermore, the corresponding vocabulary item is well known to young learners such that when presented with the image, they can concentrate entirely on the visual aspects of the object rather than on its linguistic aspects.

Day[24] used digital counts to display color in the HSB color model, an object can be assigned a color with a hue varying from 0 to 360 degrees and saturation and brightness values ranging from 0% to 100%. In the current image set, the body of the apple was rendered in red with the following parameter settings: Hue=0, Saturation=100, Brightness=100; Red=255, Green=0, Blue=0. Meanwhile, the parameter settings for the leaf were: Hue=120, Saturation=100, Brightness=100; Red=0, Green=255, Blue=0 (see Table 2).

Table 2 Color of digital count

Treatment No.	Outline Color	Outline width (pixels)	Figure No.
1	original	N/A	1
2	darker	1	2
3	darker	2	3
4	darker	4	4
5	black	1	5
6	black	2	6
7	black	4	7

According to Cai[25], the style in which Chinese characters are written has a significant effect on the readability of a document or screen display. Based on the results of a recognition test using the most commonly employed styles for Chinese characters, namely the Ming, Kai, and Li styles, the author concluded that the Ming style was the most legible. Therefore, in this study, the written instruction (the Chinese texts in these figures mean: "Count them – how many are there?") beneath the object image was written using the Ming style.

Table 3 Treatment conditions

Color	Digital count H	S	B
Red	0	100	100
Darker Red	0	100	50
Green	120	100	100
Darker Green	120	100	50
Black	0	0	0

Color	Digital count Red	Green	Blue
Red	255	0	0
Darker Red	128	0	0
Green	0	255	0
Darker Green	0	128	0
Black	0	0	0

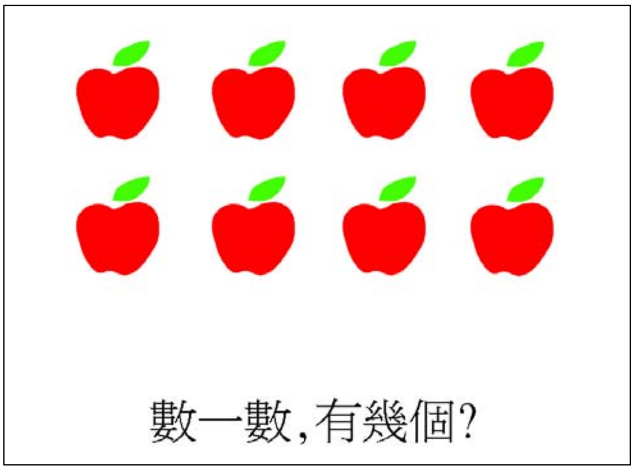

Figure 1: Outline color: S:100%, B:100%

As stated previously, this study assigned three levels to the object outline color factor and three levels to the object outline thickness factor. Therefore, as shown in Table 1 and Table 2, nine experimental treatments were theoretically possible, namely:

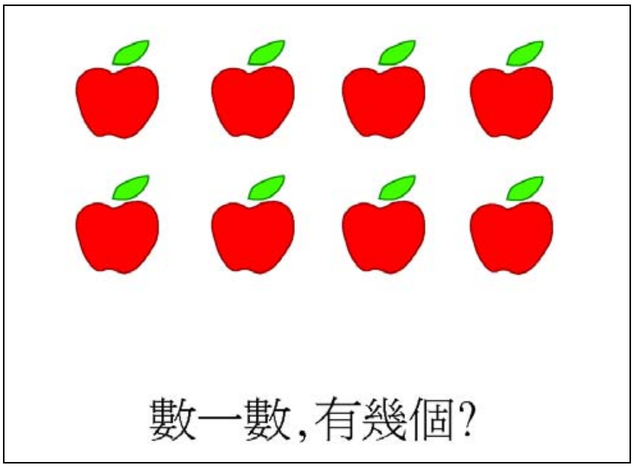

Figure 2: Outline color: S:100%, B:50%, Outline width: 1 pixel

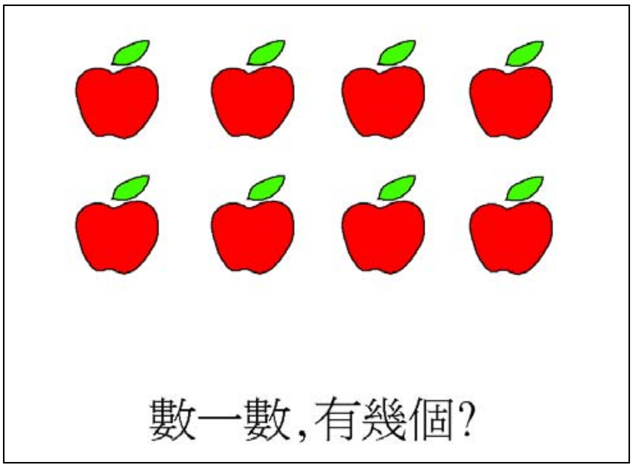

Figure 5:Outline color: S:100%, B:0%, Outline width:1 pixel

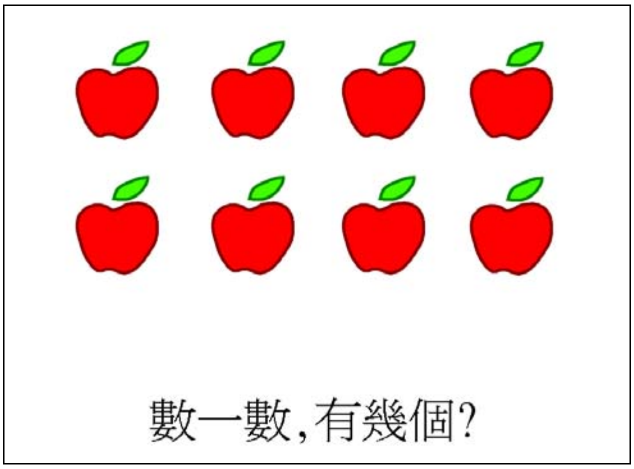

Figure 3: Outline color: S:100%, B:50%, Outline width: 2 pixels

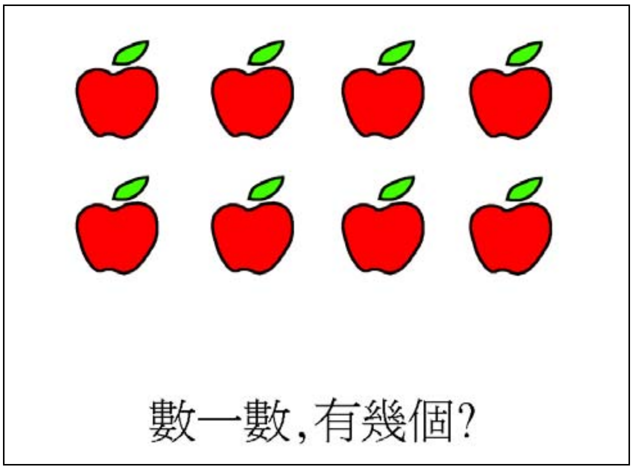

Figure 6:Outline color: S:100%, B:0%, Outline width: 2 pixels

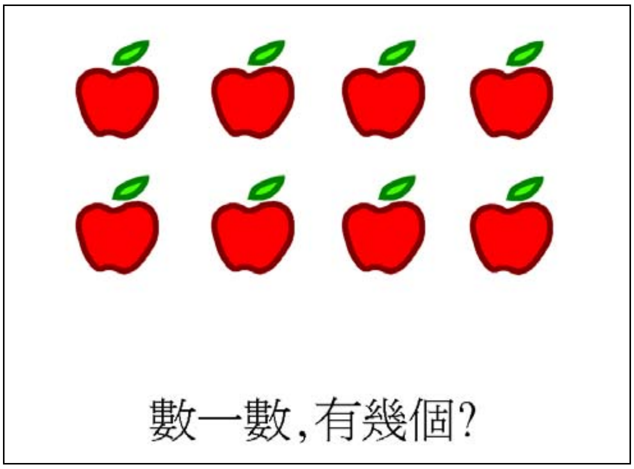

Figure 4:Outline color: S:100%, B:50%, Outline width: 4 pixels

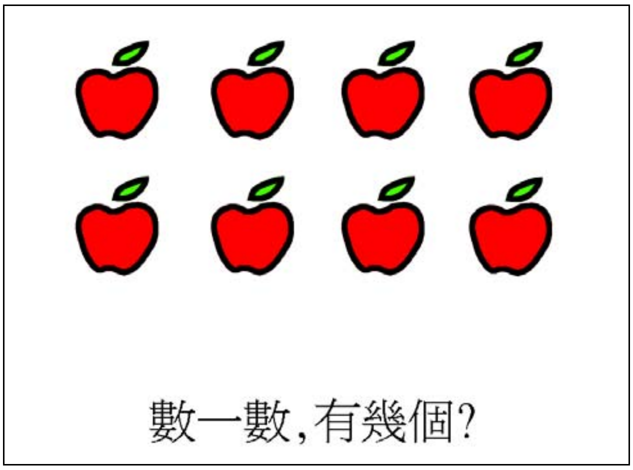

Figure 7: Outline color: S:100%, B:0%, Outline width: 4 pixels

(1) outline color: original, outline width: 1 pixels,
(2) outline color: original, outline width: 2 pixels,
(3) outline color: original, outline width: 4 pixels,
(4) outline color: darker, outline width: 1 pixels,
(5) outline color: darker, outline width: 2 pixels,
(6) outline color: darker, outline width: 4 pixels,
(7) outline color: black, outline width: 1 pixels,
(8) outline color: black, outline width: 2 pixels, and
(9) outline color: black, outline width: 4 pixels.

Since treatments (1), (2) and (3) appear identical to the viewer because the outline color is the same as that of the object itself (i.e. both are the original color), the nine treatments actually reduce to a total of seven different treatments, as shown in Figures 1-7 and summarized in Table 3. As shown in the figures, the position and color of the Chinese characters and the color and shape of the apple and the leaf are unchanged in each image, i.e. only the outline color and outline width vary from one image to the next.

2.2 Experimental Process

In Taiwan, children generally receive their first formal instruction in mathematics in either their final year in kindergarten or in the first grade of elementary school. Accordingly, this study targeted young children from these particular grades as participants in the current experimental tests. A total of 21 students studying at in Southern Taiwan kindergartens and 24 students studying at the Pao-Jan elementary school in Tainan, Taiwan, took part in the tests. The participants ranged from 5 to 9 years of age. Since the participants were young children, great care was taken to eliminate potential sources of embarrassment or anxiety when performing the tests. The tests were conducted on a student-by-student basis in the students' home classrooms and the teacher and the other participants were all asked to leave the immediate test vicinity while the experiments were in progress. Figure 8 shows a participant taking part in the test.

Prior to the tests, the researcher clearly explained the purpose of the experiment and outlined the experimental procedure. During the test, the participants were presented the seven treatments in a random sequence and were asked to describe the feelings which each one invoked, particularly with regard to the outline color and width. The participant was allowed to view each image for as long as he or she wished.

Figure 8 Participant taking part in image evaluation test

Wu[26] reported the presence of a strong contrast effect in CRT and surface media. In other words, the perceived lightness of a test color surrounded by a lighter induction color is reduced for both CRT and surface media. The author suggested that this effect is more pronounced for CRT media than for surface media. To compensate for this effect, and to ensure that the participants fully appreciated the difference in the outline effects of the various test treatments, photographs of the seven treatments were placed on the table by the participants as they conducted the tests and the distinguishing features of each image carefully pointed out by the researcher.

Having viewed all of the images, the participants were asked to rank the seven treatments in order of decreasing preference using the photographs as a guide. In ranking a series of samples, Lavin[27] employed a question and answer technique to elicit the relative preferences of young children. Shieh[28] studied the factors affecting the preference ratings of a series of prohibitive symbols. In their study, the subjects were asked to sort the symbols into 10 groups based on their subjective preferences for each symbol. The experimenters then assigned a score to each card, with those in the least-preferred group receiving a score of "1" and those in the most-preferred group receiving a score of "10". Since the participants in the current tests were all young children, the researcher used a question and answer technique to determine the children's preferences for each image. The images were then scored on a scale of 1 to 7, where 7 indicated the most preferred treatment and 1 the least preferred[20]. The scores assigned to each treatment by the 45 participants were recorded, and following the conclusion of the tests, a mean score was calculated for each.

2.3 Data analysis

The average scores obtained for each image were analyzed using SPSS and Statistica analysis of variance software. A value of $\alpha = 0.05$ was assigned to evaluate whether or not the outline color and outline width had a significant effect on the children's preferences. The various levels of the significant factors were then analyzed using the Duncan test to identify the relative influence of each level.

3 Results

Although the participants were drawn from two different classes, no significant difference was observed between the preferences of the two groups. Furthermore, the interaction between the two design factors was found to be insignificant ($p=0.869>.05$). However, the analysis of variance results indicated that the summary of all effects was significant, i.e. $F(6,308)= 11.070, p=.00<.05$. Figure 9 presents a plot of the mean scores for each of the seven treatments, where the numbers along the x-axis denote the treatment number indicated in Table 3.

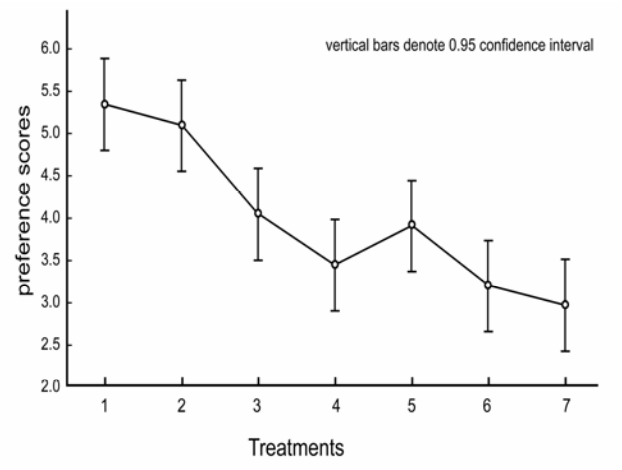

Figure 9: Plot of mean scores

The results show that the treatments were ranked (from most preferred to least preferred) as follows: (1) outline color: original (5.3333), (2) outline color: a darker color of the same hue and saturation as the original, outline width: 1 pixel (5.0889), (3) outline color: a darker color of the same hue and saturation as the original, outline width: 2 pixels (4.0444), (4) outline color: black and outline width: 1 pixel (3.4444), (5) outline color: black and outline width: 2 pixels (3.9111), (6) outline color: a darker color of the same hue and saturation as the original, outline width: 4 pixels (3.2000), and (7) outline color: black and outline width: 4 pixels (2.9778). In general, it can be seen that the preferences of the participants for the treatments with outlines with a darker color of the same hue and saturation as the original object (Treatments 2~4) tend to be more consistent (i.e. the scores are assigned over a more restricted range) than those for the treatments with black outlines (i.e. Treatments 5~7).

From the results above, it is clear that young learners prefer the object to have no discernible outline, or to have at most a thin outline with a darker color of the same hue and saturation as the original object such that the outline is virtually indistinguishable. Conversely, objects with a wider outline with a darker color of the same hue and saturation as the original or with a black outline (of any width) are less preferred.

A Duncan for post hoc test was performed to test for significant differences between the average scores of the main effects. Table 4 summarizes the results of the Duncan test. It can be seen that there is no significant difference between the treatments shown in Treatments 1 and 2 i.e. ($p=.5273>.05$). However, there is a significant difference between Treatment 1 and Treatments 3~7 i.e. ($p<.05$) and between Treatment 2 and Treatments 3-7 i.e. ($p<.05$).Finally, there is no significant difference between Treatments 3-5.

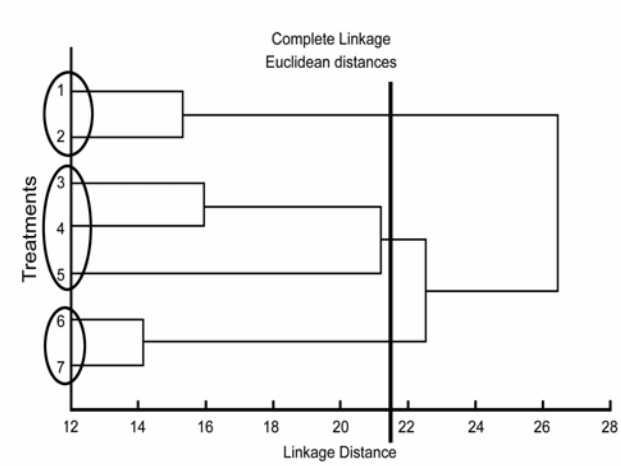

Figure 10: Cluster analysis

Table 4 Duncan test

	Treatments 2	Treatments 3
Treatments 1	0.5273	0.0012*
Treatments 2		0.0069*

	Treatments 4	Treatments 5
Treatments 1	0.0000*	0.0005*
Treatments 2	0.0000*	0.0033*
Treatments 3	0.1438	0.7303
Treatments 4		0.2276

	Treatments 6	Treatments 7
Treatments 1	0.0000*	0.0000*
Treatments 2	0.0000*	0.0000*
Treatments 3	0.0446	0.0117
Treatments 4	0.5273	0.2578
Treatments 5	0.0819	0.0255*
Treatments 6		0.5656

*p<.05

In the cluster analysis presented in Figure 10, it is apparent that the seven treatments can be divided into three groups, namely one group containing Treatments 1 and 2, and a second group containing Treatments 3-5, and a third group containing Treatments 6-7. Specifically, the preference for the group containing Treatments 1 and 2 is higher than that for the two group containing Treatments 3-7.

4 Conclusion

In the education of young children, basic counting skills tend to be emphasized at a very early age. This study has investigated the effect of the outline color and width on the preference of young children for objects presented on a PDA screen. Based on the statistical results of the current experimental trials, it can be concluded that young learners prefer the objects to have either no outline at all or at most to have a thin outline with a darker color of the same hue and saturation as the original object.

According to Shevell [29], brightness contrast has been systematically studied for more than 150 years. The present results have revealed a preference for objects with either no outline or with a thin outline (1 pixel) with a darker color of the same hue and saturation as the original object. Whittle25 conducted a study in which subjects were presented with circles with a variety of different outline widths, including no outline, 1 pixel and 3 pixels, respectively. The participants were then asked to indicate which circle appeared brighter. The results indicated that the crispening effect was greatly reduced by the presence of an outline, even one with a width of just 1 pixel. Although Whittle did not consider the impact of the outline color, i.e. the outlines were black in every case, the finding that an outline width of only 1 pixel was sufficient to reduced the crispening effect is consistent with the results identified in the current study, i.e. for each outline color, the outline with a width of 1 pixel is preferred to those with a width of either 2 or 4 pixels.

Whittle[30]showed that the presence of an outline increases the apparent brightness of an object. Similarly, Heinemann[31]showed that an inducing field in the neighborhood of the test field influenced the apparent brightness of the test field. Brown[19] commented that although color contrast is generally studied using test images presented against homogeneous backgrounds, color vision under natural conditions involves complex heterogeneous surroundings. The experimental trials conducted in the current study involve the presentation of small objects on a small screen, and a significant difference exists between the contrast of the images and that of the background. The results have shown that the young learners prefer the object to have either no outline or to have a darker outline with a width of 1 pixel. The current objects were designed using just red and green colors, with a saturation of 100 in both cases. The choice of different colors may lead to problems of simultaneous brightness, luminance contrast or chromatic contrast. However, the current results suggest that the use of an outline with a width of 1 pixel and with the same color as the object but with a darker hue and saturation represents a suitable strategy for overcoming these problems. However, in reviewing commercially available teaching materials, it is observed that many of the presented objects are designed with a black outline. Since the designers of these teaching materials are invariably adults, they tend to design objects based on their own subjective preferences. However, the results of this study suggest that the subjective visual preferences of young learners differ from those of the designer and must therefore be taken into account when designing teaching materials.

In recent years, an increasing number of schools and universities have started to use PDAs as an interface for presenting teaching materials. Additionally, many of the participants in the current study commented that they felt comfortable using the PDA interface as a learning tool since they were already familiar with similar small display devices such as mobile phones, handheld games consoles, and so forth. It certainly seems likely that PDAs will emerge as a powerful teaching / learning strategy in the future. The results presented in this study therefore provide a valuable reference for the future design of effective PDA-based teaching materials.

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