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HOW PRIOR KNOWLEDGE AND COLOUR CONTRAST INTERFERE VISUAL SEARCH PROCESSES IN NOVICE LEARNERS: AN EYE TRACKING STUDY

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ABSTRACT

This study investigates how prior content knowledge and prior exposure to microscope slides on the phases of mitosis effect students' visual search strategies and their ability to differentiate cells that are going through any phases of mitosis. Two different sets of microscope slide views were used for this purpose; with high and low colour contrasts and students' ability of recognition were investigated. Study group was consisted of forty undergraduates majoring in science teacher education at a major university in Turkey. All participants were considered novice microscope users based on their ability. Participants prior content knowledge was assessed with "Mitosis Inventory" and they were grouped based on their level of prior content knowledge. High and low level content knowledge groups took part in the study. Based on the results of the eye-tracking data; prior content knowledge was found to have an effect on participants' visual search strategies and their recognition time for the slide samples that were in high colour contrast. High prior knowledge group was able to recognize and identify the phases of mitosis correctly in a shorter period of time in comparison to low level prior knowledge group. However, no difference was found between groups for the low colour contrast slides.

KEYWORDS

Visual search, prior content knowledge, prior exposure, biology instruction, eye tracking, colour contrast

1. INTRODUCTION

In science education, use of visual materials to support verbal communication is a common practice. This way, the success of information transfer increases especially for abstract concepts. Visual representations are often used and appreciated in science education including diagrams, photographs and illustrations (Lee 2010) and they have a significant use in mainstream K-16 science education. Especially in biology education, microscopes and in astronomy education telescopes are vital instruments to provide visual information for materials that are not visible to naked eye, such as detailed visual information of cells and chromosomes provided by microscopes. Unfortunately, in most cases; students' ability to interpret visual materials is not questioned during teaching. Students' literacy level is a determinant on interpretation of materials. Novice learners are reported to struggle and be less successful in determining the relevancy of information during the interpretation of visual materials (Patrick, Carter & Wiebe, 2005).

With the increasing use of visual representations in science education, visual literacy and visual search strategies emerge as the vital skills in recognition and interpretation of visual materials at individual level. Visual search tasks are commonly used both as a tool and a method to investigate how attention influences visual information processing, namely how the visual system extracts and combines features (Zhuang and Papathomas 2011). It has been stated that the factors that increase or decrease efficiency of visual search could be categorized into image driven factors (i.e. saliency, single features, colour contrast, abrupt onset luminance contrast) and knowledge based factors (i.e. familiarity effect, novelty, experience, automaticity, pre-knowledge) (Chun and Jiang 1998). Furthermore, it has been stated that human visual attention and eye movements are in a close correlation and analysing eye movements would provide objective measures of common attentional processes (Hoffman and Subramaniam, 1995; Frey et al. 2011). Since eye movement data can provide information on how users receive and process visual information, general trend in literature has been to identify differences among novice and experts' performance with field related visual materials through eye metrics data.

Based on the data provided in literature, an experimental study was designed to explore the visual search strategies of novice learners in relation to their content knowledge level and colour contrast variations in virtual representations. More specifically, this study was designed to explore how undergraduate students' visual search strategies differ based on their prior content knowledge and the microscope slides' colour contrast variations when they were presented the same content information. In this case, the content comprised of microscope slides of onion root cells that are going through various stages of mitosis.

1.1 Visual Search

Visual search is defined as a paradigm in which a person looks for a target item among a set of distracter items (Wolfe, 1994) "to determine, as rapidly as possible, whether a target item is present or absent in a display" (Enns and Rensik, 1990, p. 323). This process involves two elements, a targeted item and distracters (Leonards et al. 2002). In visual search literature, it has been suggested that there two kinds of visual search types. These are "feature search" and "conjunction search" (Wolfe 1994; Old and Fockler 2004; Zhuang and Papathomas, 2011).

In single feature search tasks, the target differs from distracters on the basis of a single feature dimension (e.g., colour, shape, size) and reaction time and accuracy to search for the target remain generally unchanged even though the number of distracters increases in a feature search task. By contrast, in a conjunction search task, target differs from distracters on the basis of a conjunction of two or more feature dimensions (e.g., colour and shape) and reaction time increases while accuracy decreases by the increase in the number of distracters (Old and Fockler, 2004; Zhuang and Papathomas, 2011). In their Feature Integration Theory, Treisman and Gelade (1980) suggested that conjunction search occurs in two stages; the first stage of visual search is a parallel mechanism where information about one single feature dimension such as colour, size, or orientation can help in the search; each type of feature is represented by a separate feature map in the brain. The second stage of the model is a serial mechanism where each item must be considered in turn to determine whether it satisfies each required feature. When targets and distracters in visual search differ by an easily distinguishable feature such as colour, size, or orientation the reaction times decreases. On the contrary, for targets that "are not easily discriminable or differ from distracters by a conjunction of features (e.g., a particular combination of colour and shape) display size has a large effect on search times and the reaction time slope is steep" (Trick and Enns 1998, p.350).

Ngyren (1996) found that if the target stimulus is visually conspicuous then search performance could be up to 83% faster. One of the dimensions of conspicuity is differences of background colour or luminance and stimulus colour or luminance. Colour is an influential factor of graphical display and when used appropriately can lead to faster search times; conversely, poor use of colour can lead to decreases in performance (Ling and Schaik 2002, p. 224). Schaik and Ling (2001) reports that colour combinations with higher level of background and foreground contrast lead to better performance in comparison to lower contrast. In addition to colour contrast, increasing luminance contrast is also reported to be influential on visual search process and it was found that the mean fixation duration increases clearly with decreasing luminance contrast (Ojanpaa and Nasanen, 2003). Since Donk and Theeuwes (2001) have argued that luminance changes are necessary for marking to occur, Olds and Fockler (2004) suggested to further study of the question whether visual marking could occur with the present equiluminant stimuli. Background complexity is also suggested to effect visual information processing process and fixation duration and length of saccades (Crosby, Iding and Chin, 2001). Increase in the background complexity will also result in increase in information processing time and fixation duration.

Apart from those image-design driven factors (background contrast, luminance, conspicuity etc.) individual factors i.e. prior content knowledge, prior exposure, visual ability, have an effect on visual search performance. For example, success in identification and recognition of microscope display is found to be depending on integration of general knowledge, visual knowledge, high level recognition and reasoning (Pani, Chariker and Fell 2005) and content knowledge is reported to be an important component during visual processing. Moreover prior exposure to an object is suggested to improve the recognition during the upcoming encounters. The effect of this prior exposure is called "priming" and stated to improve one's ability to identify an item or an object (Schacter and Buckner 1998), not requiring conscious effort or explicit knowledge (Kristjansson, Wang and Nakayama 2002). Existing research focuses on visual search with the purpose of identifying specific patterns to support the learning process. Studies conducted with the individuals from different professions shows differences in visual search performance generally based on expertise level, prior exposure and visual display design characteristics. Various studies (i.e. Cook, Wiebe and Carter, 2008) point out the differences in interpretation of graphics among students with high and low level of content knowledge as well as among complex designed displays and well-designed displays. Results of such studies show a difference favouring experts including identification of visual images or interpretation of those (Krupinsky et al. 2006; Pani, Chariker and Fell, 2005) and also favouring well designed visual displays' compensatory effect (Canham and Hegarty, 2010). Experts in various fields learn to recognize specific patterns and make connections to the prior knowledge (Pani, Chariker and Fell, 2005).

Also eye movement studies investigating performance among various expertise levels support this difference, indicating that experts perform visual search with fewer saccadic movements with more accuracy in comparison to less trained participants (Krupinski et al. 2006; Leung et al. 2007). In addition, literature supports Henderson's (2003) suggestion that prior knowledge has a significant role on eye metrics such as fixation. Canham and Hegarty (2010) reports on a study focusing on eye fixations with visual displays which shows that with declarative knowledge subjects focus on more to relevant information rather than irrelevant information. Understanding students' interpretation of microscope slides in relation to their level of content knowledge and their expertise level, which is developed through repetition, holds a merit for the future use of such visual materials in education. Moreover, understanding the effect of prior knowledge and prior exposure with or without a well-designed environment is also important in terms of science education.

1.2 Research Questions

Shedding light on how students conduct visual search and interpret microscope slides in relation to their level of pre-existing content knowledge can help in the use and development of visual aids to support learning process in education. Therefore, this study targets novice individuals who are lack of repetition and expertise in interpreting microscope slides and investigates their visual search processes with the following questions;

1. Do the eye movements during the visual search task in different background colour contrast differ in terms of individual's prior knowledge level?
   a. Do the eye movements during the visual search task in high colour contrast images differ in terms of individual's prior knowledge level?
   b. Do the eye movements during the visual search task in low colour contrast images differ in terms of individual's prior knowledge level?
2. Do the eye movements during the visual search task in different background colour contrast differ in terms of having prior exposure to microscope view?
   a. Do the eye movements during the visual search task in high colour contrast images differ in terms of having prior exposure to microscope view?
   b. Do the eye movements during the visual search task in low colour contrast not images differ in terms of having prior exposure to microscope view?
3. Is the interaction effect between prior knowledge and prior exposure significant?

2. METHODOLOGY

2.1 Participants

A total of ninety-eight, 3rd and 4th year undergraduate students took part in the study. All participants were pre-service elementary science teachers who completed at least two general biology courses and had the basic skills of microscope use.

Prior content knowledge test on mitosis and its phases was administered to those 98 students to identify their level of prior content knowledge. Their scores were ranged from 0 to 10 with a M=5.67 mean score and sd=2.46. Participants were grouped based on their prior content knowledge levels on the phases of mitosis as high, medium or low level groups. According to their prior content knowledge scores, 40 students were appointed to either high or low level groups, 20 students to each group. High and low level groups were formed in regard to prior test scores (+/-) 1 standard deviation. Further data collection was conducted with the participation of students who were placed in either low or high level content knowledge groups. For the purpose of this study, all participants were novices in terms of their experience of using microscopes. Demographic characteristic of the study group is presented in Table 1.

Table 1. Demographic characteristic of the participants

Demographic Characteristics		F	Percentage (%)
Gender	Female	28	70%
	Male	12	30%
Grade	3	28	70%
	4	12	30%
Prior Knowledge	Low	20	50%
	High	20	50%
Prior exposure to microscope view	Yes	20	50%
	No	20	50%

2.2 Data Collection and Instruments

The prior knowledge was measured by a content test consisting of 12 multiple choice questions which was developed by a field expert who is also one of the researchers. Two more field experts outside of the study were asked to examine the questions for content validity. Questions were revised according to their suggestions. The test was administered to ninety-eight pre-service elementary science teachers for item analysis and reliability studies. The analyses yielded two questions out of 12 to be extracted from the test since the item discrimination indices for these were below 0.3. The item discrimination indices for the remaining questions ranged between 0.32 and 0.66. The reliability of the test was assessed with KR-20 reliability coefficient and it was found to be .717. Each correct answer was scored 1 point and wrong answer was scored 0 point. The maximum score of the test was 10 and the minimum was 0.

2.3 Data Analysis

A 2x2 within subject design is used for the purpose of this study. Participants were grouped by their level of prior content knowledge and their statement on either having a prior exposure to slides showing phases of mitotic division with the consideration of priming effect. During this study participants were shown a series of images consist of onion root cells. Students' task was to identify any cell/s that is/are undergoing through a phase of mitosis then click on the cell with the cursor and select the correct mitotic phase from multiple choices provided on the right side of the screen. During this task; participants were expected to go through the following steps. 1- conducting visual search 2- recognizing cell/s that are undergoing mitosis 3- recalling pre-existing knowledge and identifying the mitosis phase.

Based on prior knowledge test scores, 40 students (20 students from low prior knowledge group and 20 students from high prior knowledge groups) were selected among ninety-eight students. Experimental sessions were executed individually for each participant on an eye tracking computer accompanied by a researcher. Data collection session lasted from 10 to 15 min. The eye tracker was recalibrated for each participant before starting the data collection procedure and at the beginning an instruction was displayed including an audio-visual example. The eye track data were stored separately for further analysis.

2.4 Experimental Setting

Seven different microscope images of cells were displayed on a computer screen for each question. The microscopes slide images were grouped in two sets; high and low contrast. High contrast images were from slides that are stained with four different stains and had maroon coloured genetic material on a light blue cell background. Four of the seven questions were placed in this first set. Second set included three low contrast slides with orange coloured genetic material on a yellow cell background. The first question set was obtained from the internet and the second question set was obtained from microscope slides prepared by a field expert. A sample question from each of the question set was presented in Fig. 1.

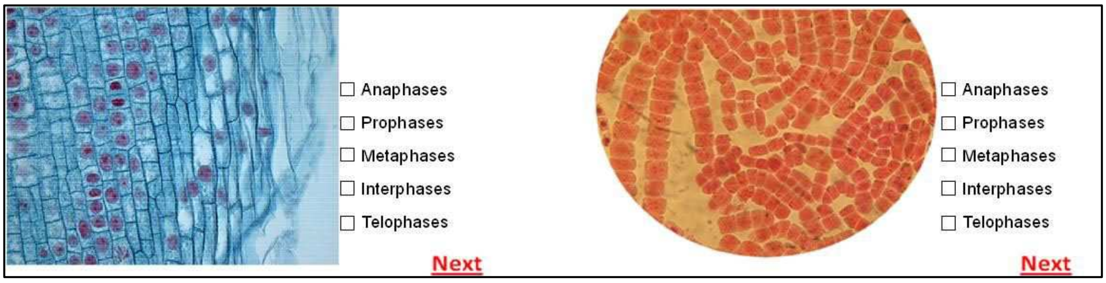

Figure 1. Sample question from different level background colour contrasts

All of the cell images were transformed to an experiment set by Tobii software on eye tracker. Tobii T120 Eye tracker was used to record eye movement data by two binocular infra-red cameras integrated within the panels of the monitor. The eye tracker was paired with 17” LCD monitor with 1280 X 768 resolutions, 120 Hz sampling rate and an accuracy of 0.5°. Among the eye movement metrics, fixation duration and time to first fixation were obtained from eye tracker for this study. Fixation duration is the amount of the time that a particular element of a design is viewed. Time to first fixation provides to measure how long it takes before a user recognizes a specific target. Undergoing mitosis phases on the cells were drawn as area of interests. Those area of interests were the areas which students required to find and recognize the right mitosis phases. Participants’ eye metrics data were recorded during the process and eye movement data on those areas were collected to analyse. Figure 2 shows the area of interest samples from each question sets.

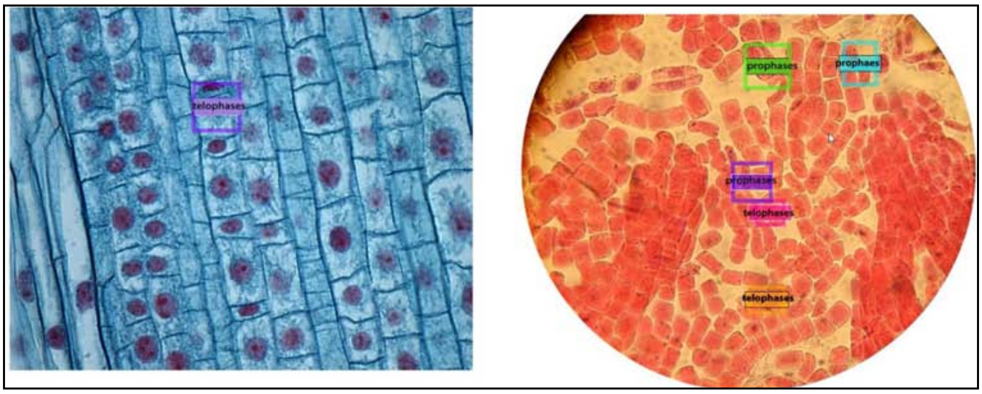

Figure 2. Area of interest samples from different level background colour contrasts questions

The images of the cells were presented on the left side of the screen while multiple choices responses of mitotic phases were placed on the right side as seen in figure 1. Participants were asked to find the cell that is undergoing through any mitotic phase and identify the cell by clicking on it with the curser and then to select the name of the mitotic phase among multiple choices presented on the right side of the screen. Participants were informed that each question could contain more than one cell vision, so they are allowed to select more than one cell and a phase consecutively. Each of the questions was displayed 20 seconds on the screen. If participants did not click on the forward button, the next question was displayed automatically after 20 seconds.

3. RESULTS

Statistics regarding dependent variables (fixation duration and time to first fixation) of low level prior knowledge-high level prior knowledge and having prior exposure-not having prior exposure in different background colours are presented in Table 2.

Table 2. Eye movement statistics across prior knowledge and prior exposure groups

			Low level prior knowledge		High level prior knowledge	
			Prior exposure (n=10)	No Prior exposure (n=10)	Prior exposure (n=10)	No Prior exposure (n=10)
Blue	Fix.Dur.	M	1.46	1.29	2.79	2.81
		Sd	.806	.764	1.27	1.94
	T_FirstFix.	M	7.04	7.52	4.66	3.98
		Sd	5.2	5.07	3.61	4.33
Yellow	Fix.Dur.	M	.818	.946	1.28	.889
		Sd	.728	.813	.852	.697
	T_FirstFix	M	4.93	3.52	3.84	5.18
		Sd	3.24	2.87	2.31	5.22

Descriptive analyses indicate that for high contrast images, students with higher content knowledge (a) fixate on the cells faster in comparison to students with lower content knowledge and (b) have a longer fixation period of time on the images. For further analysis, a two-factor MANOVA was conducted to examine eye movement differences in different colour contrasted images across prior knowledge and prior exposure factors.

Before the analyses, normality and homogeneity assumptions of covariance matrices were tested. Normality assumption was controlled with skewness and kurtosis value. Kurtosis value ranged from -.5 to 1.6 and skewness value ranged from .83 to 1.38. These results confirms the normality assumption is not violated (-10<kurtosis<10, -3<skewness<3) (Kline 2003). Homogeneity of covariance matrices assumption is tested with Box M's test and it was found that (Box's M = 54.049, F=1.428, p = .062). Since the value is not significant at 0.05 level, it was accepted that covariance matrices of groups are homogenous.

MANOVA analysis was executed to determine whether there were significant differences in time to first fixation and fixation duration across prior knowledge and prior exposure in blue background (high contrast) and yellow background (low contrast) questions. The main effect of prior knowledge was found significant (Wilk's Λ = . 677), $F(4, 33) = 3.932$, p =.010, $\eta_p^2 = .323$). However neither the main effect of prior exposure to microscope view (Wilk's Λ =. 989), $F(4, 33) = 0.91$, p = .985, $\eta_p^2 = .011$) nor the interaction effect of prior knowledge and prior exposure to microscope view (Wilk's Λ = . 880), $F(4, 33) = 1.129$, p =.369, $\eta_p^2 = .120$) were found significant.

In addition, between subject effects of prior knowledge was also examined. It was found that high level prior knowledge group was fixated on the area of interests (time to first fixation) significantly in a shorter time than low level prior knowledge group in blue background questions (high contrast); F(1, 36)=4.14, p=.049, $\eta_p^2 = .103$. In addition, in the blue background (high contrast) questions, total fixation duration of high level prior knowledge group was found to be higher than their low level counterparts F(1, 36)=12,183, p=.001, $\eta_p^2 = .253$. However, in yellow background (low contrast) questions, no statistically significant difference between prior knowledge level groups was found neither in time to first fixation F(1, 36)=.064 p=.801, $\eta_p^2 = .002$; nor in total fixation duration in the area of interests F(1, 36)=.714, p=.404, $\eta_p^2 = .019$.

4. CONCLUSION

This study investigated the effect of prior knowledge and prior exposure in different colour contrasted microscope images. The images used as questions in the study were designed in two different colour contrasts, high contrast; maroon targets on blue background versus low contrast; orange targets on yellow background, to examine whether the colour contrast facilitate the recognition process in visual search tasks.

The findings of this study revealed out that for high colour contrast image group prior knowledge has an effect in visual search tasks both in time to first fixation which shows recognition and fixation duration on the related areas. This finding is consistent with individual differences principle of Mayer (2001) in the multimedia design, which states that prior knowledge has a compensating effect on producing own mental models in multimedia learning (Mayer and Moreno 1998). In high colour contrast questions, high level prior knowledge group recognized area of interest in a shorter time and fixated on correct areas longer than other areas. This finding is also consistent with prior research which reports that combinations of colours that had higher levels of contrast between background and foreground and also higher prior knowledge generally led to better performance than combinations of lower contrast and lower prior knowledge (Ling and Schaik 2002; Theeuwes, Reimann and Mortier 2006; Huang 2008; Zhuang and Papathomas 2011).

On the other hand, visual performance of high level prior knowledge group and low level prior knowledge group was found to be similar on low contrast images, contrary to the high contrast ones. Nevertheless, based on the findings of this study it is difficult to suggest that prior knowledge effect has disappeared in low contrast background microscope images. It should be noted that time to first fixation occurs in a shorter period of time, and the difference is greater for low level prior knowledge group with no prior exposure between high and low contrast pictures (M=3.52, sd=2.87 vs. M=7.52, sd=5.07). Although this was not a main research question for this study, it may require an explanation. Remember that time to first fixation and fixation duration were the two eye tracking metrics used in this study. As a follow up to explore this difference, data were revisited and the length of first fixation duration metric results were also computed in order to explore whether these first fixations would be taken as an evidence of visual search or a mere scanning process. The length of first fixation durations were shorter in low contrast pictures (M=0.32, sd=0,1) than high contrast pictures (M=0.5, sd=0.3). Those studying the low contrast pictures had a quicker fixation but less time spent whereas those studying the high contrast pictures had relatively fixated later but stayed longer on the areas of interests. It can be speculated that their first fixation could just be interpreted as an indication of mere eye scanning on the picture. Since visual search and scanning are different cognitive processes, additional data are required to be able to predict if the prior knowledge affect disappeared or not. Furthermore, as Henderson and Hollingworth (1998) once stated, fixation duration is an indicator of the cognitive complexity. Based on the findings in this study, it can be speculated that low contrast images might increase the cognitive complexity for participants. Another interpretation could be the presentation order of the pictures. The participants were first presented the high contrast images followed by low contrast images so these results might be due to the familiarity effect. Yet, further studies investigating the role of fixation duration with counter balanced designs are required to be able to draw more solid conclusions.

Individual differences (i.e. visual ability, prior knowledge, visual attention, working memory, visual perception) are important in understanding the visual materials and also in learning from multimedia environments. However, effect of individual differences could be sensitive to the design of the learning environment. Although people could benefit from their positive individual characteristics in well-designed learning environments, ever so novel or familiar, as found by Barry and Lazarte (1995), increase in the complexity of material would diminish the advantage of previous knowledge. Reversely, well designed display designs found to be facilitating comprehension of students who has low prior knowledge (Canham and Hegarty, 2010). Further research could explore the effects of other individual differences such as gender, age, and distinctive socio-cognitive characteristics on visual processes in multimedia environments.

In conclusion, the role of visual representations cannot be ignored in science education. This study investigated visual search process by the measurement of eye movements which is an objective measurement of cognitive processes. The results revealed that for novices, who are lack of expertise in interpreting microscope images, such as participants of this study, prior knowledge has an effect when high contrast images were in question. Findings of this study can be useful for both teachers and instructional designers in science education. Instructional designers should consider design principles together with individual differences when developing visual displays. Teachers also should consider individuals' abilities and properties of visual materials when choosing instructional materials.

However, findings are inconclusive for the low colour contrast image group due the lack of qualitative measures as verbal protocols or cognitive task analysis and further studies are recommended. In addition, this study was limited to 40 students at the undergraduate level. Studies with larges samples would be needed to confirm the findings across grades and cultural settings.

REFERENCES

Barry, S. & Lazarte, A. A. (1995). Embedded Clause Effects on Recall: Does High Prior Knowledge of Content Domain Overcome Syntactic Complexity in Students of panish? *The Modern Language Journal.* 79 (4), 491-504.

Canham, M., & Hegarty, M. (2010). Effects of knowledge and display design on comprehension of complex graphics. *Learning and Instruction*. 20 (2), 155-166.

Chuang, H.-H., & Liu, H.-C. (2011). Effects of Different Multimedia Presentations on Viewers’ Information-Processing Activities Measured by Eye-Tracking Technology. *Journal of Science Education and Technology*, 1-11.

Cook, M., Wiebe, E. N. & Carter, G. (2008). The influence of prior knowledge on viewing and interpreting graphics with macroscopic and molecular representations. *Science Education,* 92: 848–867. doi: 10.1002/sce.20262.

Crosby, M., Iding, M., & Cin, D. (2001). Visual search and background complexity: Does the forest hide the trees? In M.Baier, P. J.Dmytrasiewcz, & J.Vassileva (Eds.), *Proceedings of the 8th International Conference on User Modeling*, Sonthofen, Germany, July, 225–227. Berlin, Germany: Springer.

Chun, M. M. and Jiang, (1998). Contextual Cueing: Implicit Learning and Memory of Visual Context Guides Spatial Attention. *Cognitive Psychology*. 36. 28-71.

Donk M. & Theeuwes J, (2001). Visual marking beside the mark: prioritizing selection by abrupt onsets. *Perception & Psychophysics*. 63. 891- 900.

Enns, J.T. & Rensink, R.A. (1990). Influence of scene-based properties on visual search. *Science*. 247, 721–723.

Frey H., Wirz K. T., Willenbockel V. , Betz T., Schreiber C., Troscianko T. & Konig P. (2011). Beyond correlation: do colour features influence attention in rainforest? *Frontiers in Human Neuroscience*. 5 (36).

Henderson, J. M. (2003). Human gaze control during real-world scene viewing. *Trends in Cognitive Sciences*, 7, 498-504.

Henderson, J. M., & Hollingworth, A. (1998). Eye movements during scene viewing: An overview. In G. Underwood (Ed.), *Eye Guidance in Reading and Scene Perception* (pp. 269-293). Oxford: Elsevier

Hoffman, J. E., & Subramaniam, B. (1995). The role of visual attention in saccadic eye movements. *Perception & Psychophysics*. 57, 787–795.

Huang, K. C., (2008). "Effects of computer icons and figure/background area ratios and color combinations on visual search performance on an LCD monitor." *Displays*, 29(3). 237-242.

Kristjánsson, Á., Wang, D. & Nakayama, K. (2002). The role of priming in conjunctive visual search. *Cognition*. 85(1).

Krupinski E, et al. (2006). Eye-movement study and human performance using telepathology virtual slides. Implications for medical education and differences with experience. *Human Pathology*. 7. 1543-56.

Lee, V. R. (2010). Adaptations and Continuities in the Use and Design of Visual Representations in US Middle School Science Textbooks. *International Journal of Science Education*. 32(8). 1099-1126.

Leonards, U. et al. (2002). Perceptual learning of highly demanding visual search tasks. *Vision Research*. 42(18).

Leung J.W, et.al. (2007). Performance parameters for screening and diagnostic mammography in a community practice: are there differences between specialists and general radiologists? *American Journal of Roentgenlogy*.188(1).236–241.

Ling, J. & Schaik, P. Van. (2002). The effect of text and background colour on visual search of Web pages, *Displays*. 23.

Mayer, R. (2001). *Multimedia learning*. Cambridge, UK: Cambridge University Press.

Mayer, R. E. & Moreno, R. (1998). A Cognitive Theory of Multimedia Learning: Implications for Design Principles . *Paper presented at the annual meeting of the ACM SIGCHI Conference on Human Factors in Computing Systems*, Los Angeles, CA.

Nygren,E. (1996). From paper to computer screen: human information-processing and user interface design, *Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology*, 188. Almqvist & Wiksell, Stockholm.

Ojanpaa H. & Näsänen R. (2003). Effects of luminance and colour contrast on the search of information on display devices. *Displays*. 24, 167-78.

Olds, E. S., & Fockler, K. A. (2004). Does previewing one stimulus feature help conjunction search? *Perception*, 33.

Pani, J. R., Chariker, J. H., & Fell, R. D. (2005). Visual cog-nition in microscopy. In B. G. Bara, L. Barsalou, & M. Bucciarelli (Eds.), *Proceedings of the XXVII Annual Conference of the Cognitive Science Society*, 27, 1702-1707.

Patrick, M. D., Carter, G., & Wiebe, E. N. (2005). Visual representations of DNA replication: Middle grades students‘ perceptions and interpretations. *Journal of Science Education and Technology,* 14(3), 353–365.

Schacter, D.L. & Buckner RL. (1998). Priming and the brain: review. Neuron. 20. 185–95.

Schaik, P. Van. & Ling, J. (2001). The effects of frame layout and differential background contrast on visual search performance in Web pages. *Interacting with Computers*. 13(5).513-525.

Theeuwes, J., Reimann, B. & Mortier, K. (2006). Visual search for featural singletons: No top-down modulation, only bottom-up priming. *Visual Cognition*. 14. 466-489.

Treisman, A. M. & Gelade G., (1980). A feature-integration theory of attention. *Cognitive Psychology*. 12. 97- 136.

Trick, L.M. & Enns, J.T. (1998). Lifespan changes in attention: visual search. *Cognitive Development*, 13, 369–386.

Wolfe, J. M. (1994). Guided Search 2.0: A revised model of visual search. *Psychonomic Bulletin and Review*, 1. 202-238.

Zhuang , X. & Papathomas, T. V. (2011). Cue relevance effects in conjunctive visual search: Cueing for location, colour, and orientation. *Journal of Vision*. 11(7). 6, 1–13.