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Effect of Reading Ability and Internet Experience on Keyword-based Image Search

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ABSTRACT

Image searches are now crucial for obtaining information, constructing knowledge, and building successful educational outcomes. We investigated how reading ability and Internet experience influence keyword-based image search behaviors and performance. We categorized 58 junior-high-school students into four groups of high/low reading ability and frequent/infrequent Internet usage. Participants used Google Image to complete four tasks: finding four images that match four given sentences. The results indicate that reading ability exerted a stronger influence than Internet experience on most search behaviors and performance. Positive relations were found between search performance and two behavior indicators of search outcome evaluation. Students with better reading ability tended to use/revise appropriate keywords, as well as evaluate/select images that matched multiple aspects of the task descriptions. Students with low reading ability/frequent Internet experience tended to enter a single keyword and carelessly select images, while those with low reading ability/infrequent Internet experience tended to use improper keywords and were unskillful in handling search engines. Combined, our results show that successful keyword-based image searches are strongly dependent on reading ability and search result evaluation skills.

Keywords

Information problem-solving, Image search, Search behavior, Reading ability, Internet experience

Introduction

Many individuals now consider digital cameras, cell phones with photo functions, and online photo-sharing websites to be indispensable information-sharing tools. The adages of “seeing is believing” and “a picture is worth a thousand words are now prevalent concepts in both daily life and learning. By illustrating abstract ideas through visible/concrete content and spatial arrangement, photos can convey non-verbal messages that texts are incapable or less capable of expressing. In the past two decades, visual image has become predominant form of communication across a range of learning and teaching resources, delivered across various media and formats (Bamford, 2003). Teachers frequently incorporate pictures in lectures and assignments, especially in biology, earth science, art, geography, and history domains. Students are increasingly required to attach supporting photos/figures when writing reports or creating posters to improve readability and learning effectiveness. These trends have increased the need for accurate online image search strategies. Successful image searchers are required to identify subjects, meanings, and/or elements in images, and to make judgments regarding image accuracy, validity, and value.

Many researchers have examined information-seeking behaviors and performance, but have generally focused on text rather than image searches. Text searches require the comprehension of topic-related connotations, as well as the use of associated ideas to formulate keywords. In contrast, picture or image searches require theme formulation and the ability to envision potential results. Given that many current image retrieval systems are keyword based, users must translate their visions into text keywords, and pictures stored in databases must have descriptive words or metadata that match selected keywords (Fukumoto, 2006; Hou & Ramani, 2004). Search systems transmit some pictures for users to compare, assess, and determine whether or not they need to continue a search. Accordingly, keyword-based image searches can be analyzed as complex cognitive processes involving image-text cross-referencing, observation, judgment, decision-making, and correction. Note that the presence of semantic gaps and lack of precise characteristics make keyword-based image searches more abstract and complex than text searches (Choi, 2010; Cunningham & Masoodian, 2006). For keyword-based image searches, descriptive and thematic queries are more commonly used than unique term queries. Most users perform a large amount of query modification yet are still unable to find images they desire in an effective way (Jörgensen & Jörgensen, 2005). Approximately one-fifth of all image search queries result in zero hits (Pu, 2008). Yet little is known about factors that can improve the odds for successful keyword-based image searches, which is the primary motivation for the present study.

Individuals tend to use distinctly different behaviors to perform identical search tasks—for example, reading multiple pages of search results in detail versus skimming one page of results before trying a new keyword, following multiple links versus stopping after the first webpage, or using one versus multiple search engines. Different individuals thus achieve different search outcomes and learning effects. Regarding differences in text search behaviors and performance, researchers have looked at factors such as cognitive ability (Kim & Allen, 2002; Rouet, 2003), domain knowledge (Park & Black, 2007; Rouet, 2003), thinking style (Kao, Lei, & Sun, 2008), problem-solving style (Kim & Allen, 2002), cognitive style (Ford, Eaglestone, Madden, & Whittle, 2009; Park & Black, 2007), study approach (Ford, Miller, & Moss, 2005), and Internet experience (Ford et al., 2009; Kim, 2001; Lazonder, Biemans, & Wopereis, 2000; Moore, Erdelez, & He, 2007; Park & Black, 2007; Wang, Hawk, & Tenopir, 2000; White & Iivonen, 2001). While it seems obvious that differences in individual characteristics and cognitive development may influence text-search behaviors and performance (Kim & Allen, 2002), few researchers have made the effort to test these ideas or to identify specific factors influence image searches.

Many image searches aim at locating pictures or illustrations that support text, abstract concepts, or other pictures and images. The people's motivations of image searches include a perceived need for illustrations, paintings, maps (geographic or flow), and cartoons while reading textual descriptions or looking at pictures, as well as a requirement for images to interpret abstract contents. For this study we purposefully designed image search tasks associated with texts, since one of the most common motivations is finding images to support paragraphs that lack illustrative examples.

Reading ability seems to play an important role in keyword-based image searches triggered by texts. During the search process, users are required to read sentences, comprehend their meaning, and consider relevant keywords for picture retrieval. Part of their task is comparing multiple search results and evaluating the appropriateness of pictorial information.

In addition, experience with the Internet and/or search engines is another factor that may affect search behaviors and performance (Bilal & Kirby, 2002; Hsieh-Yee, 2001). Internet novices (who are generally less flexible in terms of search strategies) tend to perceive information searches as difficult, laborious, and frustrating (Hölscher & Strube, 2000). More experienced Internet users are more likely to employ a variety of techniques (e.g., Boolean operators) or to experiment with unfamiliar tools in order to achieve better search performance.

To determine the effects of reading ability and Internet experience on keyword-based image search behaviors and performance, we established the following research questions:

1. Given specific search tasks, how do students perform image searches (search behaviors) in terms of total number of keywords, average number of Chinese characters per keyword, maximum number of viewed pages per keyword, total number of viewed pages per task, and search time? How successful are their image searches (search performance)?
2. What are the effects of reading ability and Internet experience on image search behaviors and performance? We collected quantitative indicators of search behaviors and performance as well as qualitative observational descriptions about search process.
3. Do correlations exist between individual search behaviors and search performance?

Literature review

Information and image searches

Marchionini (1995) lists the seven steps of information-seeking as recognizing and accepting information demand, defining the problem, selecting query sources, formulating a query, executing the query, examining the results, and extracting information. Brand-Gruwel, Wopereis, and Vermetten (2005) use the term information problem-solving to describe similar search actions. To achieve resolution, the multi-step and non-linear information-seeking process requires repetitive execution in addition to trial-and-error activities (Marchionini, 1995). Information searches are considered examples of complex cognitive processes, with individuals adopting different methods and sequences to find information (Hsieh-Yee, 2001; Rouet, 2003; Walraven, Brand-Gruwel, & Boshuizen, 2008).

Search engines have radically altered information-seeking habits. In developed and many developing countries, most high-school and college students (and non-students) immediately turn to the Internet to find information (Brand-Gruwel et al., 2005). They are required to actively seek and evaluate information and to construct knowledge from online searches (Bilal & Kirby, 2002). Users may acquire new concepts emerging from online information (Tsai & Tsai, 2003), which they subsequently integrate with prior knowledge (Brand-Gruwel et al., 2005). The ability to find information is frequently described as a problem-solving skill (Laxman, 2010; Park & Black, 2007; Walraven et al., 2008), one that entails planning, monitoring, evaluating, and revising—activities associated with metacognitive learning strategies (Brown, 1987). Since many search results are now displayed in some form of multimedia, learners have more opportunities to use sound, pictures, and text to construct knowledge, thus making knowledge acquisition a concrete representation of cognitive elaboration (Reigeluth & Stein, 1983). For our purposes, we viewed information searching as an active process of cognition and learning, and then investigated how different users "learn" to look for meaningful information online, and how they locate useful results.

Of all the strategies and techniques that Internet users employ, proper keyword selection is viewed by many researchers as pivotal to online search success (Fukumoto, 2006; Hsieh-Yee, 2001; Pu, 2008; Spink, Wolfram, Jansen, & Saracevic, 2001; Tu, 2005; Wang, Liu, & Chia, 2006; White & Iivonen, 2001). Search engine hits tend to be more relevant as the number of keywords used for an individual search—as Hsieh (2000) observes, the more definitive the query, the more accurate the findings. According to Pu (2008) and Walraven et al. (2008), many Internet users have trouble executing successful searches due to inaccurate statements or inappropriate structure—that is, they select keywords that are too wide or too narrow. A typical keyword-based image search process consists of typing in one or two keywords, viewing the resulting images, and repeating the process (Fukumoto, 2006). Since most search engines require keywords to locate text, pictures, and video or audio files, user selection of appropriate keywords is essential to success. Accordingly, we considered "total number of keywords" and "average number of Chinese characters per keyword" as search-behavior indicators regarding the aspect of keyword usage.

Other focal points include how users compare, evaluate, and verify information in terms of purpose, trustworthiness, and accuracy. Tsai (2004) notes that Internet searchers must evaluate the information they find until they identify the best results. Rouet (2003) suggests users improve their chances of success when they double-check search results, but others observe that most searchers want to use as little effort as possible to find the information they need (Spink et al., 2001). Assuming that judgments of accuracy influence search-result precision, we investigated the ability or motivation of users to accurately assess information. Specifically, we used "the maximum number of viewed pages per keyword," "total number of viewed pages per task," and "search time" as search-behavior indicators regarding the aspect of result evaluation.

Internet experience

Kim (2001), Matusiak (2006), and White and Iivonen (2001) are among researchers describing associations between search behaviors/performance and Internet experience. In a study of search strategies used by college students (ages 21–30) and non-students (ages 35–62), Matusiak (2006) found that students preferred keyword searches to browsing pathways, and felt more confident about their search skills due to their regular Internet usage. According to Yuan (1997), search experience enhances both user speed and the ability to make adjustments in online search approach or technique. Park and Black (2007) describe correlations between search experience and both search time and outcome, and suggest that search experience increases user familiarity with search strategies and supports the development of information search schema. According to Hölscher and Strube (2000) and Wang et al. (2000), the most experienced Internet users tend to apply more advanced techniques and express more complex behaviors in response to not immediately finding what they are looking for. Examples include using advanced search options, trying alternative search engines, and reformulating or reformatting original queries to take advantage of Boolean operators, modifiers, and phrases.

Other researchers assert that experience does not automatically result in better search performance. Wang et al. (2000) report that regardless of experience, participants in their study spent very little time looking at individual pages. Yuan (1997) asserts that experienced users may make the same number of errors as less experienced users, for instance, not knowing how to navigate around error messages without assistance. According to Lazonder et al. (2000), experienced Web users are very proficient at finding websites, but less successful in finding specific information within websites. Since finding information requires scanning, reading, and evaluation, there may be little difference between Internet novices and experts in terms of these skills or subject matter knowledge. Tu (2005) suggests that students with more Internet experience perform better on close-ended search tasks aimed at finding specific answers, while students with better overall knowledge are more adept at open-ended tasks aimed at finding less specific and more analytical information. Experienced users may be faster in locating answers, but may not be better equipped to deal with complexity and ambiguity. To reexamine the mixed results among previous research, this study investigated the possible influences of Internet experience on search behaviors and performance.

Reading ability

Reading is a complex cognitive process. Just and Carpenter (1980) describe reading comprehension as an ongoing process of identifying words, formulating propositions, and integrating until full sentence or paragraph comprehension is achieved. Gagne (1985) suggests that readers use four comprehension processes: (a) decoding, meaning that readers unlock the codes of printed texts to acquire meaning; (b) literal comprehension, to form propositions by combining the meanings of words after acquiring vocabulary-based connotations; (c) inferential comprehension, including integration, summarization, and elaboration in support of a deeper understanding of context; and (d) comprehension monitoring, referring to the ways that individuals establish reading goals, select appropriate reading strategies, determine goal achievement, and adopt alternatives if necessary. Goodman (1986) describes reading as a dynamic process in which readers interact with visual, perceptual, syntactic, and semantic cycles. He believes readers formulate mental images with visual messages that include what they actually read and what they expect—that is, they determine surface linguistic structures and phraseology before constructing connotations via in-depth structural analyses. Throughout these cycles, readers who encounter barriers re-read their texts to acquire additional messages in an effort to reconstruct meaning.

In multimedia environments, users often read or scan both texts and images. In many situations, learners can now find “help” information in the form of either graphics or text (Mayer & Massa, 2003). Paivio’s (1971, 1986) dual-coding theory (DCT) explains how people receive, handle, and integrate information from two subsystems: a verbal system for dealing with language and a nonverbal system for dealing with nonlinguistic objects and events. According to Mayer’s generative theory of multimedia learning (1997, 2001), meaningful learning requires the dual construction of a coherent mental representation of verbal and visual systems in working memory, plus systematic connections between verbal and visual representations. Comprehension depends on the successful storage of these connections along with two forms of mental representations of propositions and/or ideas in long-term memory (Plass, Chun, Mayer, & Leutner, 2003). The image search process (e.g., reading topics, comprehending text, generating keywords, building one-to-one maps between verbal and visual representations, and choosing from retrieved images) resembles this multimedia learning process. We believe image searchers must actively select and connect pieces of visual and verbal knowledge in the same manner, which explains why reading ability plays a role in performing successful image searches.

Methodology

Participants

Fifty-eight participants were selected from 227 seventh-grade students in a junior high school in Taiwan. According to past high-school entrance exam records, students from this school generally score well below the top 15% nationally. We selected 33 students identified as having strong reading skills (1 SD higher than the mean of reading ability test described in the Measures section) and 43 with weak reading skills (1 SD lower than the mean). From these 76 students, 28 were identified as frequent Internet users (8 hours or more per week) and 30 as infrequent users (5 hours or less per week). The high reading ability group consisted of 13 frequent and 15 infrequent Internet users; the respective numbers for the low reading ability group were 15 and 15.

Measures

Reading ability test and Internet usage questionnaire

The reading ability test used in this study consisted of items selected from Chinese reading comprehension questions in the Basic Competence Test for Junior High School Students, a national entrance examination used to screen students for high school placement. All test items are created and modified by a group of domain and test experts, with reliability, validity, and Rasch model data regularly monitored by the Basic Competency Test for Junior High School Center. Due to the rigorous design and revision process, we did not make any modifications for our own purposes. Test items measure ability to understand vocabulary in the contexts of factual and narrative passages. A passage consists of 200 to 300 words on a topic such as "advice from a father." For each passage, two questions are created to measure basic understanding plus the ability to make inferences and extend passage meanings. We used 12 passages and 24 multiple-choice questions to measure the reading levels of the 227 students in the original participant pool. The maximum possible score was 24; the mean in our sample was 11.16 ($SD = 4.16$).

Our Internet usage survey was designed to measure weekly Web experiences (including information searches, gaming, chatting, exchanging emails, and downloading files). The response data indicate that the participants spent an average of 7.21 hours per week online.

Image search worksheet

Based on Cunningham and Masoodian's observation (2006) that image searches usually originate from specific information requirements regarding persons, events, or activities, we created two search tasks on the topic of "animal activities" and two on "human activities." Target sentences were (a) "In a thick patch of grass, a fierce giant tiger lies looking off into the distance"; (b) "Two tiny and graceful sparrows clean their feathers in a clear stream"; (c) "A group of young boys jogs energetically on a red oval track"; and (d) "Two carefree elderly men sit at a square brown table, absorbed in a chess game."

To reduce the potential for shortcuts, we made sure that the correct images could not be found by cutting and pasting the four sentences into search engine query boxes. We also tried to maintain a consistent level of difficulty for the four sentences in terms of length, use of terms frequently encountered in daily life, and complexity of structure (Cheng, 2005). First, each of the four sentences consisted of 25 Chinese characters—the basic unit of the Chinese language, with the majority of words consisting of two characters. For example, "tiger" is written as 老虎, two characters with the literal meaning of "old tiger." Second, we used a software program from a Chinese language learning and teaching website (http://nflcr.im.knu.edu.tw/read/modules/working2.php) to analyze vocabulary frequency and found that all of the words in the four sentences were at the 3,000-word level of the 5,056 words said to be used most frequently by Taiwanese elementary school students. Finally, sentences were revised to achieve syntactic consistency.

After the participants finished their search tasks, three raters (including a computer teacher, an art teacher, and a Chinese-language teacher) were asked to individually judge how well the retrieved images matched the topic sentences as a measure of search performance. Total scores for each task ranged from 0 to 9. Students received four points for images that matched the primary subject term—tiger, sparrows, boys, or elderly men. Single points were given when images matched other sentence elements such as the main verb (e.g., lies), noun (e.g., stream), adverb (e.g., energetically), or adjective (e.g., fierce). A Kendall coefficient of agreement was used to examine consistency among the three raters; the results indicated a high level of inter-rater reliability ($W = .75$, $p < .01$). Finally, we looked for correlations between total numbers of search results for certain keywords and search performance; coefficients ranging from −0.25 to 0.06 (n.s.). In other words, no significant connections were observed between numbers of available online images and participant search performance.

Web navigation flow map

In this study, search behaviors refer to the methods used by the participants to perform image searches. We used Lin and Tsai's (2007) web navigation flow map to quantify these behaviors. CamStudio was used to record screen displays in real time. The authors reviewed these video files and recorded behaviors according to five indicators: (a) the total number of keywords used to search for relevant information (reflecting the amount of keyword revising); (b) the average number of Chinese characters used per keyword (total number of Chinese characters divided by total number of keywords used during a search task); (c) the maximum number of viewed pages per keyword (i.e., surfing search result lists, usually consisting of twenty images per page); (d) the total number of viewed pages per task; and (e) the search time from entering the first keyword(s) to downloading the final image. We used this data to create Web-navigation flow maps, such as the one shown in Figure 1 (in that figure, the total number of keywords equals 4; the average number of characters used per keyword equals 3.5; the maximum number of viewed pages per keyword equals 8; the total number of viewed pages per task equals 18; and the search time equals 332 seconds).

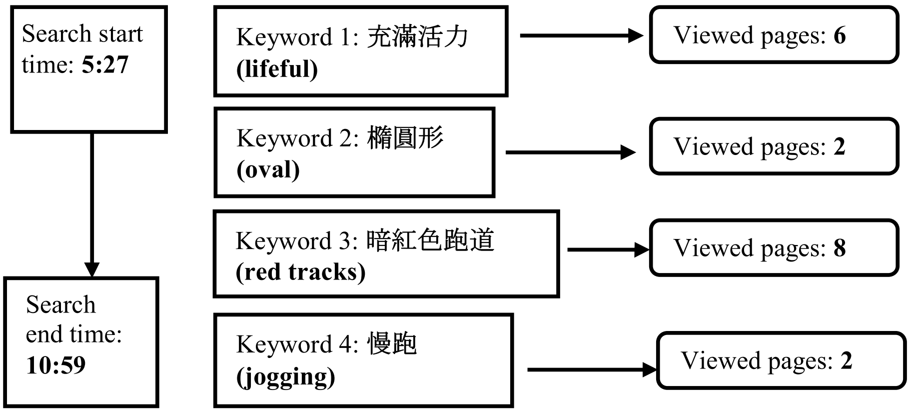

Figure 1. An example of a web navigation flow map. Chinese keywords 1–4 were translated into English in parentheses and bold type

Procedure

The study was conducted over three weeks. The reading ability test was given during week 1 (for 35 minutes). The Internet usage questionnaire was completed and Google Image features and methods were taught during week 2 (40 minutes total). Image search tasks were completed during week 3 (50 minutes). Search processes were recorded in the form of computer screenshots (qualitative data). Following task completion, individual search processes were interpreted and illustrated as Web navigation flow maps (search behaviors, quantitative data), and retrieved images were scored as performance.

Results and discussion

Descriptive statistics

Mean and standard deviation statistics for search behaviors and performance among the four groups are shown in Table 1. On average, the participants used 1.20 to 2.13 keywords per task. Our results are in general agreement with Hsieh's (2000) finding of an average of 1.5 keywords per text search for Taiwanese junior-high-school students. The participants used 2.52 to 3.23 Chinese characters per keyword, and viewed between 1.50 and 3.08 pages per keyword search. The total number of pages viewed per task ranged from 1.72 to 4.17. The average time spent per task was 92.9 to 153.8 seconds. Combined, the participants needed little time and expended little effort completing the assigned tasks. Search performance scores ranged from 2.72 to 8.05.

Table 1. Mean and standard deviation statistics for search behaviors and performance for the four groups

Reading ability	High ($N = 28$)						Low ($N = 30$)					
Internet experience	Frequent ($N = 13$)		Infrequent ($N = 15$)		Subtotal		Frequent ($N = 15$)		Infrequent ($N = 15$)		Subtotal	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*

Total number of keywords	2.13	1.69	1.70	0.56	1.90	1.21	1.20	0.29	1.35	0.54	1.28	0.43
Average number of Chinese characters used per keyword	2.73	0.65	2.77	0.82	2.75	0.73	3.23	2.25	2.52	1.00	2.88	1.75
Maximum number of viewed pages per keyword	2.48	1.47	3.08	2.06	2.80	1.80	1.50	0.78	2.17	1.12	1.83	1.00
Total number of viewed pages per task	4.15	3.36	4.17	2.39	4.16	2.83	1.72	1.15	2.73	1.82	2.23	1.58
Search time	151.29	108.38	153.80	68.64	152.63	87.55	92.95	42.83	153.62	79.85	123.28	70.11
Search performance	8.04	0.87	8.05	0.89	8.04	0.87	3.15	1.47	2.72	1.53	2.93	1.49

Effects of reading ability and Internet experience on search behaviors

We found a significant main effect of reading ability on the total number of search keywords ($F = 7.359$, $p < .01$), but no main effect from either Internet experience or interaction between reading ability and Internet experience. Participants with better reading comprehension skills tended to use more keywords in their searches. According to these data and search process observations, better readers were more likely to find appropriate images from the search engine hits they received from initial keywords, or to quickly and continuously modify keywords when results did not meet their expectations. An example of a search task (b), a high reading ability student conducted six searches using various keywords: "stream," "two sparrows," "sparrow in stream," "clean feathers," "sparrows clean feathers in stream," and "clean feathers & sparrows." This explains why the standard deviation of "total number of keywords" for the high reading ability group ($SD = 1.21$) was significantly larger than that for the low reading ability group ($SD = 0.43$, $F = 2.81$, $p < .01$). Low-ability readers often used keywords that reflected less important aspects of the task sentences (e.g., "grass," "looking off," "clear stream," "red oval track," or "a brown table") or keywords that were irrelevant to the task descriptions (e.g., "bear," "cat," "flower," "waterfall," or "gun.").

Freeman (2001) suggests that during the reading process, continuous changes occur between actual texts and texts constructed in the minds of readers. Even when reading the same article multiple times, readers are sensitive to differences among reading experiences. We observed better readers quickly re-reading topics and constructing new keywords, while poor readers used only one keyword and tended to terminate searches when results did not immediately match the requirements. This suggests that students with poor reading skills have difficulty in interpreting search topics, formulating appropriate keywords, and using correct terms.

No significance was noted for main and interaction effects of reading ability and Internet experience on the average number of Chinese characters per keyword. Keyword lengths among the four groups were very similar—between two and three characters. Students in the high reading/frequent Internet user group used an average of 2.73 characters per keyword, with relatively small dispersion ($SD = 0.65$). Students in the low reading/frequent Internet user group used an average of 3.23 characters per keyword, with a much larger dispersion ($SD = 2.25$, $F = 3.61$, $p < .001$). According to search process observations, better readers tended to use fewer than four characters in their keywords, while poorer readers frequently used whole sentences or longer phrases. In addition, poor readers tended to add (or delete) one or two words to (or from) original keywords when those keywords were unsuccessful. For example, for task (c) one low-ability reader initially used the keywords "red oval track," then added the verb "<jog> red oval track," and finally added the subject "<boy> jog red oval track." These results imply that better readers are more capable of using concise, accurate phrases to perform successful image searches.

We found a significant main effect of reading ability on maximum number of viewed pages per keyword ($F = 6.312$, $p < .05$); other effects were not significant. According to this finding, better readers were more competent in viewing more pages of image search results. We also observed that most students in the high reading group continued checking/rechecking images even after finding pictures that met the task criteria, implying that they took greater care in evaluating retrieved images.

There was a significant main effect of reading ability on total number of viewed pages per task ($F = 10.431$, $p < .01$); other effects were not significant. In other words, better readers viewed almost twice as many search result pages for each task than did poorer readers. According to our observations, better readers were more likely to review a larger number and broader range of images due to their ability to try various keywords and to evaluate whether retrieved images matched the task descriptions.

Significance was not found for main and interaction effects of reading ability and Internet experience on search time. Although time differences were observed between the two groups (152.63 seconds for high reading versus 123.28 seconds for low reading; 122.12 seconds for frequent users versus 153.71 seconds for infrequent users), between-group differences were not significantly larger than within-group differences. In short, each search task required between two and three minutes for completion.

Effects of reading ability and Internet experience on search performance

The data indicate a significant main effect of reading ability on search performance ($F = 243.747$, $p < .001$); other effects were not significant. Search performance was measured as the degree of relevance between a downloaded picture and the concepts expressed in the task sentence. According to search process observations, pictures selected by poor readers frequently matched a single feature of the search requirements (e.g., general pictures of tigers, sparrows, stream, boy, or track), but did not reflect other features such as verbs, adjectives, or adverbs in the topic sentences. For example, task (a), the two pictures (Figures 2A and B) were chosen by two high-ability readers. Both were given 9 points (the highest score) because they matched multiple aspects of the text descriptions, while the three pictures (Figures 3A, B and C) chosen by three low-ability readers received scores of 4, 4 and 1 because they matched only the terms "tiger" or "grass." The results indicate that better readers evaluated texts and images carefully and critically. They tended to discriminate, analyze, and interpret texts and images to ascertain meaning, and to understand the subject matter of texts and images. Then they cross-referenced and integrated visual and textual actions, objects and symbols.

Students in the low reading ability/infrequent Internet user group had more difficulty choosing keywords and were less familiar with Google Image—two factors that affected their search efforts and the time required for task completion. In contrast, students in the low reading/frequent Internet user group tended to type in any single keyword, randomly scan search results, and show less care in completing tasks. They were less likely to make the effort to verify information. This observation is consistent with Shenton and Dixon's (2004) assertion that teenagers are less likely than older Internet users to evaluate information quality, and more likely to believe that the most easily accessed information is sufficient for answering inquiries.

Figure 2. Examples of pictures chosen by high-ability readers in response to the prompt, "In a thick patch of grass, a fierce giant tiger lies looking off into the distance."

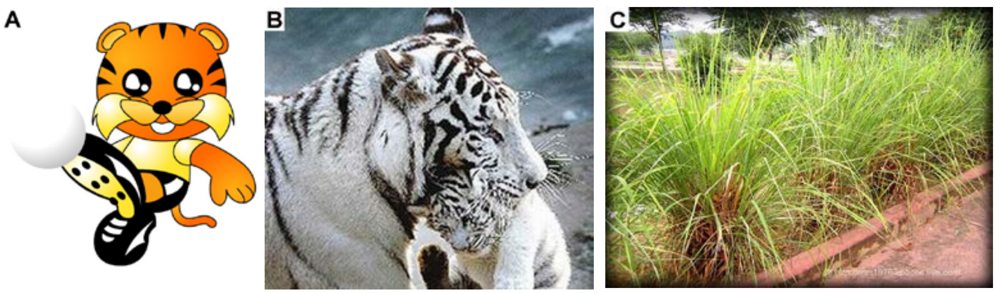

Figure 3. Examples of pictures chosen by low-ability readers in response to the prompt, "In a thick patch of grass, a fierce giant tiger lies looking off into the distance."

Correlations between search behaviors and performance

Significant positive correlations were found between performance and both the maximum number of viewed pages per keyword ($r = .362$, $p < .01$) and total number of viewed pages per task ($r = .386$, $p < .01$), but not for any other indicator. These two indicators signify student ability or motivation to view and evaluate image contents. The more effort the participants allocated to reviewing and evaluating search results, the greater the potential that their images would be relevant to all perspectives of task concepts.

No relationship was found between performance and keyword-based behavior indicators. These results are not consistent with those reported by Tu (2005) for text searches. Tu found positive relationships between search performance and both the total number of keywords and the average number of Chinese characters per keyword. We believe the difference lies in the distinction between image and text searches—that is, the requirement for keyword-based image searches that search engines compare keywords with image topics, image file names, and/or text attached to images. There are many examples of image descriptions that do not accurately reflect image content; therefore, users may not be able to find corresponding pictures even when they make good decisions regarding keywords. For example, although many participants used identical keyword "sparrows," they selected very different pictures from the search results. Figures 4A and B were retrieved from page 7 and 8, respectively, of the returning search results, both were given 9 points because they matched all text descriptions of task (b), while Figures 4C and D were both retrieved from page 1 of the returning search results both received scores of 4 because they only matched a single element "sparrows." In such cases, in order to obtain accurate pictures, users must be careful when evaluating pictures. These results support our assertion that the maximum and total numbers of viewed pages serve as indicators of image search success.

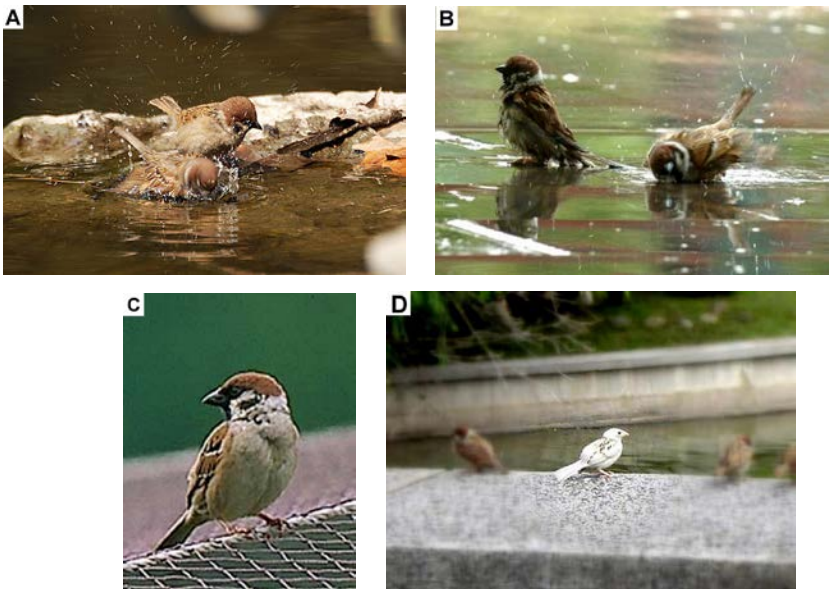

Figure 4. Four pictures, A to D, were found via the identical keyword "sparrows" for search task (b) "Two tiny and graceful sparrows clean their feathers in a clear stream."

Conclusions

Our data support the notion of reading ability being an important factor influencing keyword-based image search success. Compared to less skilled readers, better readers were more likely to find appropriate images based on effective keywords, or to be more adaptive in changing keywords when results were inadequate. Better readers were also more effective in terms of selecting and evaluating search results to obtain quality images. Our data also support the notion that successful image searches (including understanding textual intention, generating mental image, making inferences, generating accurate keywords, evaluating pictorial intention, and comparing image content with text descriptions) require the incorporation of both verbal and pictorial systems. Image search success represents a manifestation of visual literacy; according to our results, reading comprehension is probably a fundamental factor in visual literacy.

Internet experience did not exert a strong influence on image searches, a finding that agrees with text search results reported by Wang et al. (2000), Lazonder et al. (2000), and Tu (2005). Since learning how to use image and text search engines is an easy task for most Internet users (Wang et al., 2006), we believe the key to teaching image search skills resides in task description and evaluation. This would explain why online experience does not directly add to or detract from search behaviors and performance.

The use of computer technologies for problem-solving is fast becoming a required daily life skill for students and non-students alike. This transformation is affecting education in terms of knowledge transfer and construction because students are increasingly required to take the initiative to seek and construct their own knowledge pools. Accordingly, learning effectiveness is increasingly impacted by information collection, analysis, assessment, and integration. Educators must focus on teaching Internet search and website information assessment skills, and helping students use information contained in various types of images. For example, computer teachers must introduce how Web search results could be ranked and remind students that the most useful/correct knowledge or quality information does not necessarily be placed at the top. Even though keyword-based image searches may appear simple to execute, we observed sharp distinctions between students at various reading skill levels. A lack of reading ability affects students' ability to search effectively. Therefore, how to modify instructional approaches for students with specific characteristics such as good/poor reading skills, improve student's reading abilities further, and build up their visual literacy are missions for teachers to continue pouring in more efforts.

We found that most participants surfed the Web following the sequence of search result lists and became bored or frustrated after viewing a small number of links. Only good readers were capable of selecting satisfactory images facing a bunch of retrieved outcomes; hence the ranking and clustering functions of search engines seem to need certain improvement. The authors suggest that search engine algorithms can be modified to include functions that reorganize content from search results or classify search results according to correlation. Furthermore, when creating new information retrieval products, exploring specialized technologies aimed at various types of information embedded in websites, and working with the unique features of Web 3.0 semantic content tagging, search engine developers need to consider how users construct mental representations when performing image searches. Technology designers need to consider more personalized functions in terms of inquiry strategies, filtering techniques, and multiple media indexing. For example, AI technologies can be used to differentiate individual abilities (e.g., reading, spatial or visual literacy) and Internet usage habits (e.g., result page and keyword usage), so as to provide appropriate auxiliaries. However, it remains to be examined whether these new functions support greater search result accuracy or simply impose additional cognitive burdens.

We acknowledge at least two study limitations. First, the small sample size and limited ranges of age, educational level, and Internet experience mean that the results cannot be generalized to non-junior-high-school populations. Second, we used short texts (sentence-length) as prompts for searches, whereas image searches can also be triggered by abstract concepts or other images. Whether reading ability still plays an important role in such situations requires further study.

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References

Bamford, A. (2003). *The visual literacy white paper*. Retrieved June 03, 2011, from http://www.adobe.com/uk/education/pdf/adobe_visual_literacy_paper.pdf

Bilal, D. & Kirby, J. (2002). Differences and similarities in information seeking on the Web: Children and adults as Web users. *Information Processing and Management, 38*(5), 649–670.

Brand-Gruwel, S., Wopereis, I., & Vermetten, Y. (2005). Information problem solving by experts and novices: Analysis of a complex cognitive skill. *Computers in Human Behavior, 21*(3), 487–508.

Brown, A. L. (1987). Metacognition executive control, self-regulation, and other more mysterious mechanisms. In Weinert, F. E. & Kluwe, R. H. (Eds.) *Metacognition, motivation, and understanding* (pp.65–116). Hillsdale, NJ: Erlbaum.

Cheng, C. C. (2005, April). *Measuring reading difficulties of vocabulary, meanings and sentences.* Paper presented at the Sixth Chinese Lexical Semantics Workshop, Xiamen, China.

Choi, Y. (2010). Effects of contextual factors on image searching on the Web. *Journal of the American Society for Information Science, 61*(10), 2011–2028.

Cunningham, S., & Masoodian, M. (2006, June). *Looking for a picture: An analysis of everyday image information searching.* Paper presented at the 6th ACM/IEEE-CS Joint Conference on Digital Libraries, New York, USA.

Ford, N., Eaglestone, B., Madden, A., & Whittle, M. (2009). Web searching by the "general public": An individual differences perspective. *Journal of Documentation, 65*(4), 632–667.

Ford, N., Miller, D., & Moss, N. (2005). Web search strategies and human individual differences: Cognitive and demographic factors, Internet attitudes, and approaches. *Journal of the American Society for Information Science and Technology, 56*(7), 741–756.

Freeman, A. (2001). The eyes have it: Oral miscue and eye movement analysis of the reading of fourth grade Spanish/English bilinguals. (Unpublished doctoral dissertation). University of Arizona, Tucson, Arizona.

Fukumoto, T. (2006). An analysis of image retrieval behavior for metadata type image database. *Information Processing & Management, 42*(3), 723–728.

Gagne, E. D. (1985). *The cognitive psychology of school learning.* Boston, MA: Little, Brown.

Goodman, K. S. (1986). What's whole in whole language. Portsmouth, NH: Heinemann.

Hölscher, C. & Strube, G. (2000). Web search behavior of Internet experts and newbies. *Computer Networks, 33*(1–6), 337–346.

Hou, S. & Ramani, K. (2004, September). *Dynamic query interface for 3D shape search.* Paper presented at the DETC '04 ASME 2004 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Salt Lake City, USA.

Hsieh, P. Y. (2000). *Information search for round up all: When mouse meets robin.* Taichung, Taiwan: National Museum of Natural Science.

Hsieh-Yee, I. (2001). Research on web search behavior. *Library & Information Science Research, 23*(2), 167–185.

Jörgensen, C. & Jörgensen, P. (2005). Image querying by image professionals. *Journal of the American Society for Information Science and Technology, 56*(12), 1346–1359.

Just, M. A. & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review, 87*(4), 329–354.

Kao, G. Y. M., Lei, P. L., & Sun, C. T. (2008). Thinking style impacts on Web search strategies. *Computers in Human Behavior, 24*(4), 1330–1341.

Kim, K. S. (2001). Information-seeking on the web: Effects of user and task variables. *Library & Information Science Research, 23*(3), 233–255.

Kim, K.S. & Allen, B. (2002). Cognitive and task influences on Web searching behavior. *Journal of the American Society for Information Science and Technology, 53*(2), 109–119.

Laxman, K. (2010). A conceptual framework mapping the application of information search strategies to well and ill-structured problem solving. *Computers & Education, 55*(2), 513–526.

Lazonder, A. W., Biemans, H. J. A., & Wopereis, I. G. J. H. (2000). Differences between novice and experienced users in searching information on the World Wide Web. *Journal of the American Society for Information Science, 51*(6), 576–581.

Lin, C. C., & Tsai, C.C. (2007). A "navigation flow map" method of representing students' searching behaviors and strategies on the Web, with relations to searching outcomes. *CyberPsychology & Behavior, 10*(5), 689–695.

Marchionini, G. (1995). Information seeking in electronic environments. Cambridge, MA: Cambridge University Press.

Matusiak, K. K. (2006). Information seeking behavior in digital image collections: A cognitive approach. *The Journal of Academic Librarianship, 32*(5), 479–488.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*(1), 1–19.

Mayer, R. E. (2001). *Multimedia learning*. New York, NY: Cambridge University Press.

Mayer, R. E., & Massa, L. J. (2003). Three facets of visual and verbal learners: Cognitive ability, cognitive style, and learning preference. *Journal of Educational Psychology, 95*(4), 833–841.

Moore, J. L., Erdelez, S., & He, W. (2007). The search experience variable in information behavior research. *Journal of the American Society for Information Science and Technology, 58*(10), 1529–1546.

Paivio, A. (1971). *Imagery and verbal processes*. New York, NY: Holt, Rinehart & Winston.

Paivio, A. (1986). *Mental representations: A dual coding approach*. Oxford, England: Oxford University Press.

Park, Y., & Black, J. B. (2007). Identifying the impact of domain knowledge and cognitive style on Web-based information search behavior. *Journal of Educational Computing Research, 36*(1), 15–37.

Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (2003). Cognitive load in reading a foreign language text with multimedia aids and the influence of verbal and spatial abilities. *Computers in Human Behavior, 19*(2), 221–243.

Pu, H. T. (2008). An analysis of failed queries for web image retrieval. *Journal of Information Science, 34*(3), 275–289.

Reigeluth, C. M., & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional design theories and models: An overview of their current states* (pp. 338–381). Hillsdale, NJ: Lawrence Erlbaum.

Rouet, J. F. (2003). What was I looking for? The influence of task specificity and prior knowledge on students' search strategies in hypertext. *Interacting with Computers, 15*(3), 409–428.

Shenton, A. K., & Dixon, P. (2004). Issues arising from youngsters' information-seeking behavior. *Library & Information Science Research, 26*(2), 177–200.

Spink, A., Wolfram, D., Jansen, B. J., & Saracevic, T. (2001). Searching the Web: The public and their queries. *Journal of the American Society for Information Science, 52*(3), 226–234.

Tsai, C. C. (2004). Information commitments in web-based learning environments. *Innovations in Education and Teaching International, 41*(1), 105–112.

Tsai, M. J., & Tsai, C. C. (2003). Information searching strategies in Web-based science learning: The role of Internet self-efficacy. *Innovations in Education and Teaching International, 40*(1), 43–50.

Tu, Y. W. (2005). Eighth graders' Web searching strategies and outcomes: The role of epistemological beliefs. (Unpublished master's thesis). National Chiao Tung University, Hsinchu, Taiwan.

Walraven A., Brand-gruwel S., & Boshuizen H. P. A., (2008). Information-problem solving: A review of problems students encounter and instructional solutions. *Computers in Human Behavior, 24*(3), 623–648.

Wang, P., Hawk, W. B., & Tenopir, C. (2000). Users' interaction with World Wide Web resources: An exploratory study using a holistic approach. *Information Processing & Management, 36*(2), 229–251.

Wang, H., Liu, S., & Chia, L. T. (2006, October). *Does ontology help in image retrieval? A comparison between keyword, text ontology and multi-modality ontology approaches.* Paper presented at the 14th annual ACM international conference on Multimedia, Santa Barbara, USA.

White, M. D., & Iivonen, M. (2001). Questions as a factor in web search strategy. *Information Processing & Management, 37*(5), 721–740.

Yuan, W. (1997). End-user searching behavior in information retrieval: A longitudinal study. *Journal of the American Society for Information Science, 48*(3), 218–234.