“Draw me the Web”. Impact of mental model of the Web on information search performance of young users

Jérôme Dinet
Université Paul Verlaine -Metz
Campus du Saulcy, BP 30309
F-57006 Metz cedex 1
+33(0)3-87-54-73-05
dinet@univ-metz.fr

Muneo Kitajima
AIST, Tsukuba
1-1-1, Umezono, Ibaraki 305-8568
Tsukuba Central 2, Japan
+81-29-861-6650
kitajima@ni.aist.go.jp

RESUME
Cette expérimentation conduite avec 51 enfants français a pour but d’étudier les relations entre les performances des jeunes usagers lors de recherche d’information et leur modèle mental du Web. Chaque participant était invité (a) à renseigner un questionnaire visant à évaluer son expérience avec le Web, (b) dessiner ce qu’est le Web pour elle/lui, et (c) réaliser deux recherches d’information sur le Web. Les résultats ont montré que plusieurs modèles mentaux du Web existent chez ces jeunes usagers, indépendamment de leur expérience avec le Web. De plus, les résultats ont confirmé que le modèle mental pourrait être lié aux performances.

Mots clés
Recherche d’information, Usager, Modèle mental, World Wide Web.

ABSTRACT
The aim of this experiment conducted with 51 French children was to understand the relationships between children’s information search performances and their mental model of the Web. Each participant was individually asked (a) to complete a demographic questionnaire asking experience with the Web, (b) to draw a picture of her/his perception about the Web, and (c) to perform two search tasks. The results showed that several mental models existed for young users about the Web, independently of their experience with the Web. Moreover, the results confirmed that mental model of the Web could have an effect on the performance.

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Categories and Subject Descriptors
H.3.3 Information Search and Retrieval, H.5.2 User Interfaces

General Terms
Human factors, Performance.

Keywords
Information search, User, Mental model, World Wide Web.

1. INTRODUCTION
For many years, two kinds of scientific studies have been conducted about information search behaviours and/or performances when users are young users:

- first, lots of studies investigated difficulties and strategies of children searching for information on digital environments [1] [2] [3] [8] [9][19] [37];
- second, children’s understanding and perception of the Web emerged as an important topic in the research area of children and the Internet [15] [41] [42] [43], with potential theoretical significance (e.g. impact of age, genre and experience with the Web), social (e.g., protecting children on the Internet) and educational implications (e.g. enhancing learning processes).

The aim of this paper is to understand the relationships between children’s information search performances and their mental model of the Web (i.e., the relationships between the two previous points). More precisely, this paper presents an experiment interested in the impact of mental models of the Web and efficiency when end-users are young users (aged from 10 to 14 years-old).

1.1 Mental model and information search
Research in human factors and human–computer interaction (HCI) suggested that it is mental models that enable people to interact with complex devices, including computer systems [12] [29] [44]. Fein, Olson, and Olson [11] defined mental models as knowledge that users have about “how a system works, its component parts, the processes, their interactions, and how one component influences another”(1993, p.57).

The mental representation of our environment is crucial to navigate efficiently and to search for accurate information. For many years, lots of studies investigated the impact of mental representation on human information searching in physical

environment (e.g. [18] [21] [28] [39]) and/or in a computer simulation of a physical environment (e.g., [6] [35] [40]). But, on the one hand, few studies investigated this impact of mental model in digital environment such as the Web. On the other hand, very few researchers are interested in this impact for young users.

At the beginning of the World Wide Web (WWW or Web), Kerr [23] demonstrated that difficulties with "wayfinding" are common among users of electronic information systems. A study of strategies (textual, graphic, colour) for cuing users to their location in a database showed that the presence or absence of physical cues was less important to successful searching than the user's ability to represent internally the structure of the information. Users with more detailed and complete impressions of the database searched faster. But the variety of different representations of the database suggest it may be very difficult to create generic mental models as a help to novice users.

Thatcher & Greyling [37] conducted one of the first experiments to gain an understanding of how people (users, potential users, and non-users) conceptualise the structure of the Web. More precisely, it was the first study conducted to know what form of mental models (from Johnson-Laird's point of view; Johnson-Laird, [20]) people hold about the Web in order to understand how one goes about searching for information.

Some previous case studies tended to demonstrate that the mental models of users could influence the efficiency during information search tasks [9] [32] [37] in the following sense: the mental models of experienced users are richer, more abstract and more complete than less experienced users, and these experienced users were more efficient.

According to us, the study conducted by Thatcher & Greyling [37] is particularly relevant for three reasons: it was a preliminary investigation looking at a method of accessing users' mental models of the Web; it was a study based on the drawing technique to access mental models of the Web from a wide range of individuals; results and analyses of the drawings performed by the participants (51 university students) demonstrated different categories of mental models.

According to Yan [41], mental models of the Web can be located between two orthogonal axes: technical complexity and social complexity of the Web. In her study, Yan [40] investigated people's understanding of the technical and social complexity of the Web across four age groups: 5-8 years old (n=21), 9-10 years old (n=25), 11-12 years old (n=35), and adults (n=27). The people's understanding of the technical complexity of the Web was assessed by questions such as "What is the Internet?", "Is email the Internet?", "Where is the Internet?". The social complexity was assessed by questions such as "What kinds of good things could the Internet do to us?", "What kinds of bad things could the Internet do to us?", or "What kinds of things do you like most on the Internet?". In other words, according to Yan [40], the users' understanding of the social complexity of the Web corresponds to the understanding of the positive and negative social consequences of the Web and how much users are aware of Web safety. Technical complexity and social complexity were coded at four levels (minimal, partial, sophisticated, and scientific). One of the most interesting results obtained by Yan [40] is to demonstrate that age rather than online experience (i.e. duration and frequency of Web use) is a better predictor of participants' understanding of the technical and social complexity of the Internet. Identical results have been obtained in two similar studies conducted some years later [41] [42].

In other words, for some researchers ([5] [25] [26] [27] [32] [36] [37]), mental models are related to experience with the Web. For other researchers ([34] [40] [41] [42]), age is a better predictor of users' mental model of the Web. Be as it may, all the researchers agree on the fact that strategies and difficulties of users performing an information search in a digital environment are related to their mental models about this digital environment. So, to identify the user's mental model of the Web is crucial because this mental model determines the users' behaviours during information search tasks [33] [36] [44].

1.2 Drawing technique and mental model

Mental models are difficult to operationalize and their definition depends on the theoretical point of view of "mental model" [29]. Irrespective of the definition, the two main methods used to solicit users' mental models of information search and/or information retrieval systems are interview and think-aloud protocol (e.g., [4] [22]). But, interview and think-aloud protocol are very difficult to use with young participants. Moreover, drawing is more and more used to obtain information about mental models when objects are abstract, complex, based on scientific jargon and highly technological [7] [24].

The way in which individuals represent knowledge directly affects their assimilation, manipulation, and application of that knowledge. As Dorum and Garland said [10], it follows that determining and understanding the mental models adopted by users is an essential prerequisite to the design of websites, particularly where efficient navigation is important. The understanding that users have of an information space, i.e., their mental model, affects their ability to navigate through it quickly and efficiently [13], and becoming lost or disoriented is often associated with difficulties in forming mental models [15] [16].

In his study conducting to explore how age, goals, and experience influence search approaches during Web and Web online catalogue searching, Slone [34] chose to conduct two audio taped interviews with volunteer's participant and to observe their online sessions. The researcher approached participants who were attempting to use the library's stand-alone online catalogues and asked them to take part in the study by doing their information search on the Web. The resulting participant sample consisted of seven children younger than 13 years, four participants aged 13 to 17 years, two people aged 18 to 25 years, seven people aged 26 to 35 years, eight people aged 36 to 45 years, and three people who were 46 years and older. Results have mainly shown that verbalisations and thinking-aloud procedure are really difficult with the youngest participants and interfere with the information search behaviours.

Drawing is one of the preferred activities performed by children. Consequently, the drawings and their analysis are largely used in some specific domains related to psychology and/or psychiatry with children and adolescents. In parallel, drawing is often used by designers and ergonomics of digital or physical environments for obtaining information about mental models of users. It is surprising to note that drawing is rarely used to obtain information about mental models of young users.

By considering drawing as a primitive form of communication, it seems to be possible to use this technique to collect data about mental models when participants interacting with digital environments are young people [44]. Gray [13] was the first case

studies using drawing as a means to examine children's conception of computers. Other studies are based on the same procedure, i.e. to point out that question like "Please draw a diagram of picture of it" (e.g., [30] [31]).

Based on the analysis of the drawings performed by 44 users of the Web, Zhang [44] identified four mental models of the Web:

(a) *Technical view*: participants with this view looked at the Web mainly as a composition of computers, servers, modems, and CPUs. Some of the drawings or drawings descriptions also included people as a part of these systems;

(b) *Functional view*: users with this view saw the Web as a place for shopping (books, movies, tickets, and clothes), entertainment (movies, games, and chatting), emailing, paying bills, looking for information (news, sports, weather, and maps), and doing research (libraries);

(c) *Process view*, or *search engine centred view*: users with this view saw search engines as the centre of the Web; all information branches off from search engines;

(d) *Connection view*: many participants viewed the Web as a global-wide connection between information, people, computers, mobile phones, and Webpages. They also viewed the Web as an important communication channel.

So, the main results of the study conducted by Zhang [44] were to demonstrate that drawings are effective in representing people's mental models of the Web and users with different mental model styles showed different performances and feelings during the interaction with the Web. For instance, the technical view users took the least time to find a mediocre answer (i.e., not a good answer) for searching information on the Web, but these users felt the least difficulty with this task and the most satisfied with their performances.

2. METHOD

With an experiment conducted with 21 French children (aged from 10 to 14 years-old), we tried to gain insights into the relationships between children's information search performances and their mental models of the Web.

2.1 Participants

The study had 51 participants, recruited in one French secondary school. Among these 51 children, there were 23 10–11-year-olds (M = 10 years 5 months, SD = 2.8 months), and 28 13–14-year-olds (M = 13 years 4 months, SD = 3.45 months), with approximately equal numbers of boys and girls. These children were recruited from one suburban public secondary school, and routinely had 50-min informal computer classes once or twice a week.

2.2 Data gathering and procedure

Three instruments has been used for data collection: a questionnaire asking children's experience with the Web; a drawing activity picturing their perceptions about the Web, as well as drawing annotations; and two search tasks.

2.2.1 Experience with the Web

Data were collected on participants' online experience, through a series of questions presented in a survey-like format used in previous studies [40] [41] [42]. This variable categorizes participants' direct experience with the Web at home and school. Participants answered 9 short questions that mainly probed three aspects of online experience: (a) Specific experience with different Websites (e.g., "Do you use Facebook?", "Do you use Twitter?", "Do you use Monjournal6.fr?"); (b) Duration of Web use (i.e., "How long have you used the Internet at school?", "How long have you used the Internet at home?"); and (c) Frequency of using the Web (i.e., "How often have you used the Internet at school?", "How often have you used the Internet at home?"). On the basis of the responses given, online experience was coded at three levels [39]: minimal (never or hardly use the Web at home and school); limited (use the Web at home or school for 1–2 year(s) several times a week); and extensive (have online experience for 3 years or longer, and use the Web on a daily basis.

2.2.2 Drawing task

For the drawing task, each participant received the same instruction: "Please draw a picture of your perceptions about the Web". After drawing, participants could write one or two sentences to describe their drawings. Drawings were classified from bottom up into four categories based on themes that they represent established by Zhang [44]. Drawings are very illustrative, but they are sometimes hard to interpret. The coders could refer to the descriptions (i.e., sentences) provided by the children along with the drawings to ensure correct interpretation. Four judges (four researchers in psychology who are not the authors of this paper) coded the drawings twice within one month. Each of the four judges coded the same 51 drawings independently. After the four coders discussed the conceptual level at which the drawings should be coded to make the comparison between different groups possible, the agreement rate reached 94.11%. After discussion, undecided drawings were either categorized into the most appropriate categories or excluded (in this experiment, only one drawing performed by one child in age group 13-14 years-old).

2.2.3 Information search tasks

The two information search tasks were: (1) "What city held the arrest of Louis XVI?", and (2) "What treaty has transformed the EEC in European Union?". These two questions simulate information search tasks that are common and typical to children recruited in French secondary school. This intended to provide a familiar context for participants to perform searches on the Web so as to elicit their typical Web searching behaviours. Note that none of the participants knew the answers of the two questions. During the two information search tasks, for all participants, the computer showed the Google home page at the start of the study session. All participants were individually told that they were free to search for information in any manner they wanted. After completing the first information search, the participants were asked to write their answer on a sheet of paper. They were given a 10-min break, after which they began their second Web search followed by completion of the information search for the second topic (instructions were identical to those the first topic). All Web pages were shown in Internet Explorer 7. The browser window was sized to 1024x741 pixels. The use of tabs or additional windows was prohibited.

3. RESULTS

3.1 Experience with the Web

Data obtained about children's online experience with the Web through a series of questions have mainly showed that all participants had an extensive level of knowledge (Table 1). In other words, except for two children in age group 10-11-years-old who had a limited level of knowledge, our participants had online

experience for 3 years or longer, and used the Web on a daily basis.

Table 1. Genre, age group and experience with the Web for the study participants.

Age group	*n*	*Male* *Number (%)*	*Age* *Mean (SD)*	*Experience with the Web* *Number (%)*		
				Minimal	*Limited*	*Extensive*
10-11	23	12 (52.17%)	10.5 (0.30)	0 (-)	2 (8.69%)	21 (91.3%)
13-14	28	16 (57.14%)	13.4 (0.34)	0 (-)	0 (-)	28 (100%)

3.2 Mental models of the Web

Six mental model styles were identified based on drawings and drawing descriptions. Four of these 6 mental model styles were identical to those identified by Zhang [44] ((1) "Technical view", (2) "Process view", (3) "Functional view", and (4) "Connection view"), and the four judges agreed to add two new mental model styles: "Techni-functional view" and "Functional-connection view":

(5) *Techni-functional view*: children with this view see the Web as a composition of computers, servers, and CPUs and as a place for shopping, entertainment, and looking for information. Figure 1e shows a typical example of this view of the Web.

(6) *Functional-connection view*: in this case, users view the Web as a network of place for shopping, entertainment, and looking for information in a global-wide connection. Figure 1f is an example.

Sample of drawings of each of the six categories are presented in figure 1 below.

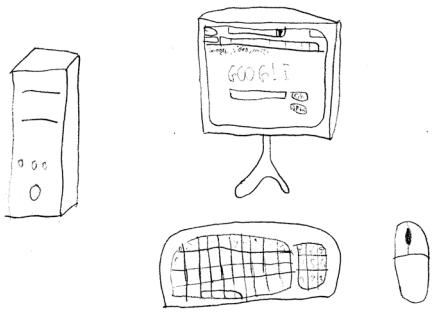

Figure 1a. Technical view

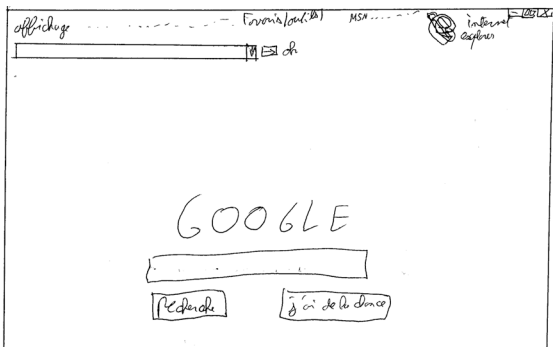

Figure 1b. Process view

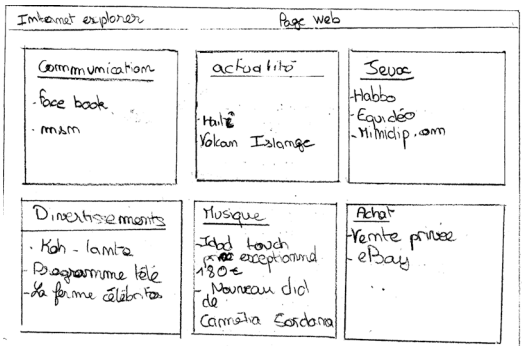

Figure 1c. Functional view

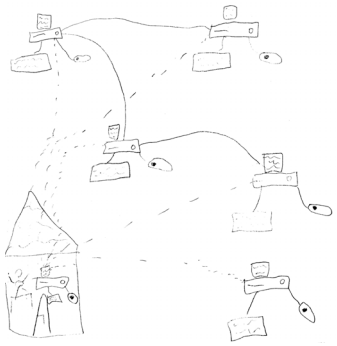

Figure 1d. Connection view

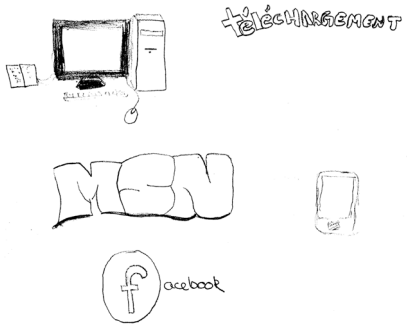

Figure 1e. Techni-functional view

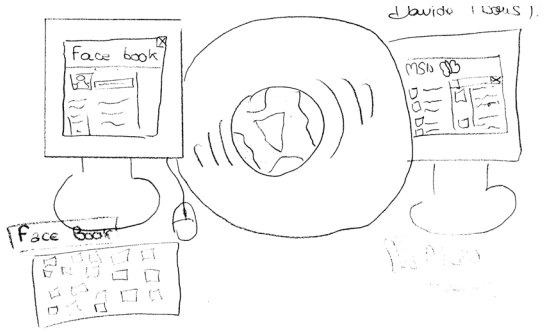

Figure 1f. Functional-connection view

Figure 1. Sample of drawings for each of the six categories.

Non-parametric analyses revealed significant difference in the distribution of the mental model styles among age group (χ^2 =

37.08, $\nu = 5$, $p < .001$; Figure 2). Process view is dominant for children aged from 10-11 years-old (43.47%) while functional view is dominant for children aged from 13-14 years-old (42.85%). For children aged from 10-11 years-old, only two users (8.69%) have a functional view while ten users (43.47%) have a process view ($\chi^2 = 20.23$, $\nu = 1$, $p < .0001$). For children aged from 13-14 years-old, twelve users (44.4%) have a functional view while only three users (11.11%) have a process view ($\chi^2 = 10.71$, $\nu = 1$, $p < .001$). No other significant difference has been noted.

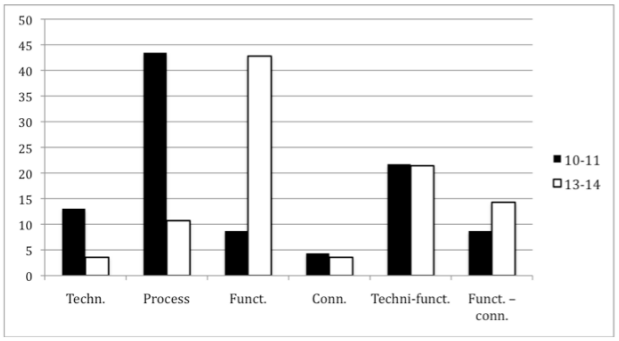

Figure 2. Distribution (percentage) of the study participants according to their age group and the six types of mental model of the Web.

3.3 Impact of mental model on performance

Performance of our participants has been estimated with two indicators (table 2): session length (i.e., the time from the start to the end of the search in seconds), and the mean number of Webpages visited.

Table 2. Performance of our participants for the two information search tasks.

Age group	*View*	*n*	Session length Mean (*SD*)	Mean number of Webpages visited
10-11	Techn.	3	**567** (115)	**6.5**
	Process	10	454 (78)	4.5
	Funct.	2	301 (92)	4
	Conn.	1	442 (-)	2
	Techni-funct	5	356 (121)	3
	Funct.-conn.	2	312 (155)	3.5
13-14	Techn.	1	**329** (-)	**5**
	Process	3	290 (132)	4
	Funct.	12	194 (126)	2
	Conn.	1	241 (-)	3.5
	Techni-funct	6	276 (109)	3
	Funct.-conn.	4	204 (84)	4.5

Non-parametric analyses revealed significant difference in the session lenght among age group ($\chi^2 = 12.04$, $\nu = 1$, $p < .01$). Children aged from 10-11 years-old took more time to perform the two information search tasks than children aged from 13-14 years-old (respectively, 372 seconds *vs* 255.6 seconds).

Even if no other significant difference has been obtained (among the two search topics and among the mental models), we noted two other interesting findings (Table 2):

- first, the session length and the mean number of Webpages visited for children with a technical view of the Web were largest whatever the grade is;
- in parallel, the session length and the mean number of Webpages visited for children with a functional view of the Web were the least important whatever the grade is.

In other words, children with a functional view of the Web tended to be more efficient than children with a technical view of the Web.

4. DISCUSSION

The aim of this study was to gain insights into the relationships between children's information search performances and their mental models of the Web. Several interesting results have been obtained.

From a theoretical point of view, our results show that several mental models exist for young users about the World Wide Web, independently of their experience with the Web. This finding differs from the results obtained by [5] [25] [26] [27] [32] [36] [37] and confirms the results obtained by [34] [40] [41] [42]: age is a better predictor of young users' mental model of the Web than the experience with the Web. We hypothesise that the change of mental model of the Web is essentially under the influence of development of human cognition and the cognitive maturity.

One of the other main results obtained in our study is to demonstrate a difference in mental models between the 10-11 years-old group and the 13-14 years-old group. The youngest children see search engines as the centre of the Web (process view) while the "oldest" children see the Web as a place for their daily activities (shopping, entertainment, emailing; functional view). Because our participants in the two age groups are not the same, we do not conclude of an existence of a developmental change in the mental models. So longitudinal studies are needed. Moreover, with our participants, our results tend to show that "mixed" mental models can exist. If four mental models very different have been identified in previous studies, some drawings performed by our participants are a "combination" of these mental models. More precisely, some children see the Web as a composition of computers, servers, and CPUs and as a place for their daily activities. And in the same way, some children view the Web as a network of place for their daily activities in a global-wide connection.

Moreover, given that our results confirm that age is a good predictor of young users' performance during online searching [8] [40] [41] [42], they tend to show that mental model of the Web could be related to the performance. In the experiment, the following tendency has been found: pupils with a functional view of the Web tend to be more efficient than pupils with a technical view of the Web in terms of the session length and the number of Web pages they visited for obtaining answers to the questions.

From a methodological point of view, our study confirms that drawing is relevant to gain understanding of the users' mental models [7] [24], especially when these users are young users. Understanding and facilitating human-information interaction requires considering the process of interaction, as well as the resultant changes in both the human as information seeker and the

objects that convey information. It requires methods and tools of investigation that complement our results.

Rather than suggesting an implementation of the mental models in Websites design, our findings demonstrate that mental models could be of great importance in informing design decisions for the accurate and efficient use of Web. Because the understanding that users (here, children) have of an information space, i.e., their mental model, affects their ability to navigate through it quickly and efficiently [10] [13], it is important to continue this kind of research. Moreover, it could be interesting to investigate the impact of cross-cultural differences on these mental models.

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