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Do Sign Language Videos Improve Web Navigation for Deaf Signer Users?

I. Fajardo*[1], E. Parra[2], J. J. Cañas[3]
[1]University of Valencia, Spain
[2]Barcelona Media-Centre d'Innovaccio
[3]University of Granada, Spain

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The efficacy of video-based sign language (SL) navigation aids to improve Web search for Deaf Signers was tested by two experiments. Experiment 1 compared 2 navigation aids based on text hyperlinks linked to embedded SL videos, which differed in the spatial contiguity between the text hyperlink and SL video (contiguous vs. distant). Deaf Signers' performance was similar in Web search using both aids, but a positive correlation between their word categorization abilities and search efficiency appeared in the distant condition. In Experiment 2, the contiguous condition was compared with a text-only hyperlink condition. Deaf Signers became less disorientated (used shorter paths to find the target) in the text plus SL condition than in the text-only condition. In addition, the positive correlation between word categorization abilities and search only appeared in the text-only condition. These findings suggest that SL videos added to text hyperlinks improve Web search efficiency for Deaf Signers.

The inclusion of sign language (SL) on the Web might improve Deaf Signers' information access and optimize their educational and social opportunities, but is a twofold challenge: technological and functional.

The technological challenge is being successfully overcome because technological advances have made it possible, for instance, to display videos containing SL content at high temporal and spatial resolutions on the Web. Videos can be encrypted in small areas of the Web sites, avoiding the need to open a different browser window to play them, thus reducing the potential user "disorientation" that occurs when users lose their way in their navigation through a Web site or hypertext system (Nielsen, 1990) or lose "their sense of location and direction in a nonlinear document" (Utting & Yankelovitch, 1989, p. 58). Furthermore, SL videos not only serve to transmit contents passively (e.g., news in a digital newspaper) but, thanks to hypervideo technology, they can also contain hyperlinks to other parts of the same video, other videos, or regular Web pages (e.g., the *Signlinking* of Fels, Richards, Hardman, Soudian, & Silverman, 2004; *Hypercafe* by Sawhney, Balcom, & Smith, 1996).

The functional challenge is still in the phase of formulating questions with few answers. It is necessary to discover how a new technology such as SL videos embedded in Web pages affects the basic process of information search for Deaf Signers or, in other words, it is necessary to address questions such as: Do SL videos serve as cues to guide information search on the Web? Would SL videos complement or interfere with text links? The answer to these questions cannot be directly derived from a Web information search model and, to our best knowledge, has not been empirically tested with Deaf Signers. Most Web information search models focus mainly on how users assess and select text hyperlinks or labels (e.g., Brumby & Howes, 2008; Fu & Pirolli, 2007; Kitajima, Blackmon, & Polson, 2000). However, could such models account for those situations in which information scent cues are nontextual? Solving this question is especially relevant for users who are not efficient in the use of text

*Correspondence should be sent to I. Fajardo Bravo, Facultad de Psicología, Departamento de Psicología Evolutiva y de la Educación, University of Valencia, Blasco Ibañez, 21, Valencia, Spain (e-mail: infabra@uv.es).

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cues or users who usually navigate in a second language, such as Deaf Signers (Fajardo, Cañas, Salmerón, & Abascal, 2006; Smith, 2006). In fact, quoting Pirolli (2004):

> the most significant current problem for the future development of the models concerns the analysis of non-text information scent cues[1], such as graphical icons, animations, and so on, and the relation of proximal information scent cues to non-text distal content such as video and music. (p. 36)

Therefore, the main goal of the two experiments presented in this article was to determine how users draw on nontext information cues or, more specifically, to determine the efficacy of Web information search using nontext cues (SL videos) combined with text cues. We hypothesized that SL videos would produce two effects: (a) improving search efficiency and efficacy (increasing accuracy and lessening disorientation) and (b) reducing the requirement for verbal abilities during a Web search.

Therefore, the goal of Experiment 1 was to compare the different alternatives for a navigation aid based on SL. The two options generated differed in video–text hyperlink spatial contiguity and were named *distant* (videos were displayed in an area of the Web pages that was far from the related textual links) and *contiguous* (videos and textual hyperlinks are close to each other in the Web page) video-based SL navigation aids (visual representations of both versions can be seen in Figures 1 and 2 and supplementary material, videos of the signing conditions). In Experiment 2, the more usable of the two SL-based navigation aids used in Experiment 1 was compared with a text-only hyperlink version of the same Web site. In addition, in order to study the relation between search and verbal ability of Deaf Signers, a set of verbal tests were applied in both experiments. The rationale for these research goals is described below.

Deaf Signers' Web Information Search

A Web hypermedia system is composed of a set of information nodes connected by hyperlinks. Information search refers to the user's behavior of looking for pieces of information within or between Web pages or hypermedia by means of queries in search engines and/or by following hyperlinks. Whatever the aid used, one of the most influential theories of information search, the Information Foraging Theory (Pirolli & Card, 1999), predicts that a particular hyperlink will be followed when the trade-off between information

Figure 1 Page of the Web site used in the distant condition of Experiments 1.

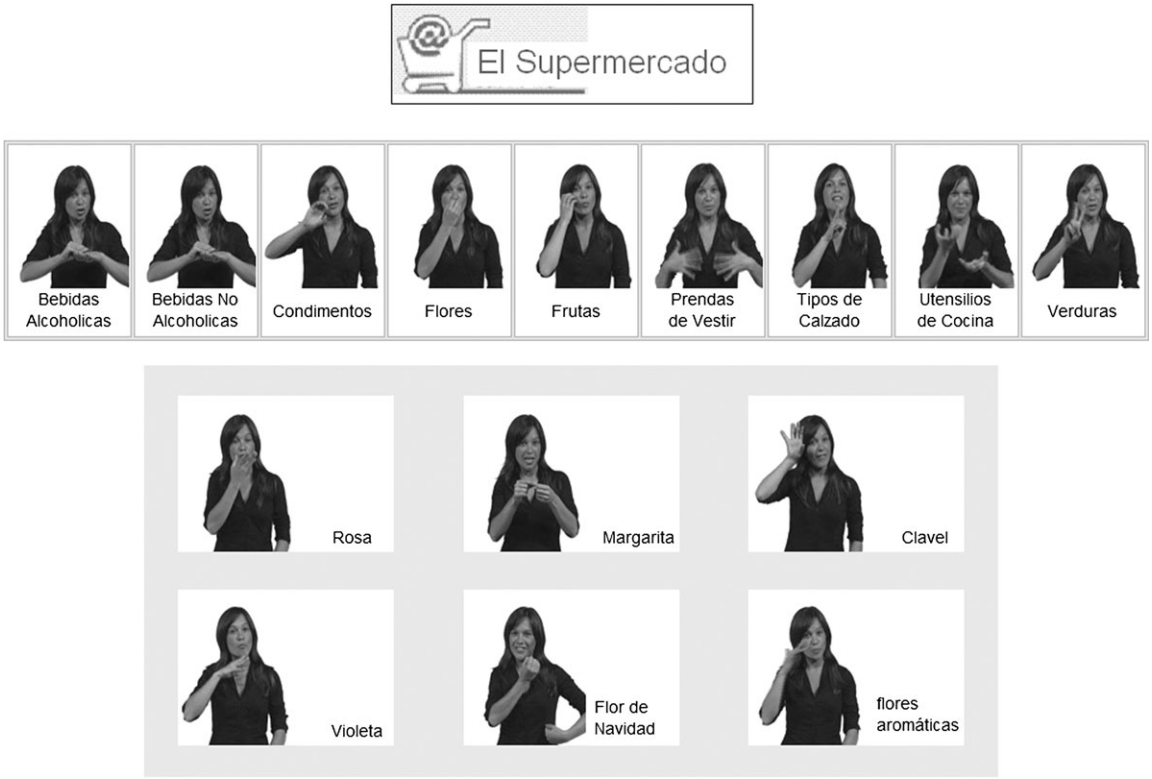

Figure 2 Page of the Web site used in the contiguous condition of Experiments 1 and 2.

gain and cost (difficulty) of accessing it is low. Therefore, in order to calculate such trade-offs, individuals have to assess the semantic similarity between the search goals and hyperlink choices (information scents) presented on a Web page or hypermedia node. Supporting this hypothesis, Pirolli (2004) found that users tend to leave the site when the information scent (measured by independent judges in Pirolli's experiment) for encountered Web pages declines. In order to choose which links to assess and then select, users could apply simple strategies, such as *satisficing* (sequential assessment of links and selection of the first one which satisfies an aspiration level), *assess-all-accounts* (assess all available items and select the best one), or more complex context-sensitive strategies (for a review, see Brumby & Howes, 2008). Whatever the strategy, there is some kind of semantic comparison between the choices and goals involved.

This apparently simple process might become a problem for hearing users, theoretically experts in oral and written language, who may be influenced by factors such as the semantic similarity and location of link choices on the page (e.g., Brumby & Howes, 2008; Pierce, Parkinson, & Sisson, 1992) or the Web structure (McDonald & Stevenson, 1996). For instance, Pierce et al. (1992) found that when the set of alternatives in a menu search task was less semantically relevant to the goal, hearing participants used a more redundant search behavior and were less likely to accurately select the target item.

For Deaf Signers, this type of effect, which affects Web users in general, could be accentuated, as the semantic cues are frequently encountered in text format, a second language for most of them. Actually, a common empirical finding is that deaf people, especially those who are prelingually deaf, are not proficient in oral language use at several levels: vocabulary acquisition and competence (Hermans, Knoors, Ormel, & Verhoeven, 2008; Kelly, 1996), grammar and reading comprehension (e.g., Alegría & Leybaert, 1985; Goldin-Meadow & Mayberry, 2001), and so on. In this sense, Fajardo, Cañas, Salmerón, and Abascal (2009) observed that Deaf Signers' reading skills correlated significantly with the percentage of targets

found and with knowledge acquisition during a Web search task. The use of graphical hyperlinks (icons) for very common and familiar concepts (e.g., sport, food, drink) seems to facilitate Deaf Signers' search (Fajardo, Arfé, Benedetti, & Altoé, 2008), but they result in an unusable solution when the concepts to be represented by means of icons are unfamiliar and abstract. In the latter case (unfamiliar and abstract icons), the performance of both hearing and, paradoxically, Deaf Signers is even lower with icons than with text hyperlinks (Fajardo et al., 2006). The fact that icons do not form a standard or universal language with unequivocal meaning for Web users could explain the effect of graphical hyperlink disadvantage.

These previous findings lead us to the conclusion that the provision of scent cues in SL, the stronger language of Deaf Signers, could improve knowledge or lexical access and, consequently, Web information search for this group of users. SL, as a natural language, has the same features as any other natural spoken language; that is, it has its own morphological, syntactic, and semantic rules (Stokoe, 1974) and thus it should be easier to interpret by native signers than abstract icons or printed texts coming from oral languages. As some studies have shown, SL seems to be able to convey complex information for native signers in a similar way that oral languages do for their native users (Rodriguez-Ortiz, 2007a), although this facilitation may vary as a function of several factors such as metacognitive skills, content knowledge, or educational level (Marschark, Sapere, Convertino, & Seewagen, 2005).

Hence, the facilitation of SL cannot be presupposed but needs to be tested. This was the general goal of the two experiments presented in this article. The first step was to select a navigation aid in SL (Experiment 1). One of the more sophisticated preexisting alternatives is the *Signlinking* system (Fels et al., 2004) consisting of an SL video stream that contains embedded anchors or links. Each link has a period of time within the video clip defined by the author (e.g., a specific sign). When the video reaches a link, a "link indicator" is shown to notify the user of it. Then the user can click and follow the link or continue playing the content. Therefore, both the content and the navigation aid are conveyed in SL. The cost of editing and implementation of this system is high, and it works as an alternative to text Web sites. However, we were interested in developing a navigation aid that could be easily implemented, added to any preexisting text Web site, and could provide simultaneous text and SL navigation. Therefore, collaborating with a company of graphic designers (Signocom Producciones) who are experts in the design of multimedia for Deaf people, we developed the two types of navigation aids in SL described above. Both aids consisted of videos embedded in small Web areas that contain SL translation (performed by human signers) of each of the text hyperlinks of the menu. The two aids, which differed mainly in the spatial contiguity between the SL videos and text hyperlinks, were called *distant* and *contiguous* SL-based navigation aids. As we said before, the first step was to contrast empirically the efficiency of both alternatives (Experiment 1). In order to make predictions about the efficiency of each alterative, we used the "spatial contiguity principle" (Mayer, 2005). This principle is commonly applied to the design of documents that combine words and pictures, but it can be easily generalized for documents combining words and videos. It states that the user's understanding of the message transmitted by words and corresponding pictures will improve when they are presented near to rather than far from each other on the page. Therefore, based on the spatial contiguity principle, we expected that the *contiguous* aid would facilitate Web search performance better than the *distant* aid.

The second goal of our experimental series was to study the influence of Deaf Signers' verbal ability on Web information search. In particular, we focused on word categorization abilities (which refers to the organization and use of knowledge about word categories and their exemplars—e.g., animals: cat, dog; vehicles: car, truck; emotions: happy, sad) because (a) it seems to be an area affected in Deaf people by the late acquisition of oral language and reading literacy and (b) it might be involved in Web search. Some studies have found that deaf students underperform their hearing peers in tasks that require the use of taxonomic or categorical verbal information (e.g., Marschark & Everhart, 1999; Marschark, Convertino, McEvoy, & Masteller, 2004). For instance, Marschark et al.

(2004) found that although deaf and hearing students' knowledge reflected in a word association task was similar, deaf students obtained a lower score than hearing students in a verbal analogy task where participants had to resolve analogies of the type "banana is to fruit what rose is to _____ (answer: flower)." They suggest that this result supports the idea that the problem for deaf students is not a lack of verbal knowledge but knowing when and how to apply it spontaneously in context. However, one could ask: Is this verbal ability relevant for Web searching? Most commercial Web sites or hypertext systems organize their contents in categories, thus making users apply their categorical knowledge to make navigation decisions among a hierarchy of Web pages. For instance, in order to find the item *Digital camera*, located in a distal location of an online shop, users will have to decide which of the proximal cues (category names) of the menu on the home page (e.g., Literature, Photography, or Travels) will lead to the target. Therefore, problems in word categorization abilities could be partially responsible for the information search difficulties of Deaf Signers.

For the preliminary exploration of the hypothesis about categorization abilities involvement in Web search, Fajardo et al. (2008) carried out a study in which a group of 30 Deaf Signers and 31 Hearing non-Signers were asked to perform two tasks: a categorization test (to categorize items—exemplars—as belonging to one of two categories, Snodgrass & McCullough, 1986) and a Web information search (to find items in a digital supermarket). Contrary to prediction, although Deaf Signers were slower than Hearing participants in both the categorization test and the search task, the categorization scores did not correlate with search efficiency; that is, the categorization and Web search did not seem to be related.

This hypothesis was tested again in the two studies presented in this article, but using a more complex categorization test. In particular, we adapted the Verbal Analogy Task used in Marschark et al. (2004). The rationale behind this replication with a more complex task is that, as suggested by Marschark et al., deaf and hearing students would not differ as much in knowledge organization as in its automatic application in unfamiliar contexts. In both verbal analogy and Web search tasks, users would have to identify similarities or differences between concepts and automatically apply their categorical knowledge to solve the problem. Therefore, if Deaf Signers have difficulties in solving verbal analogies, they would show difficulties in information search. Such difficulties would be reduced thanks to the use of SL cues, which would make it easier for them to access their knowledge in long-term memory.

In summary, the goals of Experiment 1 were as follows:

1. To compare the efficiency of two video-based SL navigation aids (distant and contiguous) to improve Deaf Signers' information search. In particular, according to the spatial contiguity principle, we expected Deaf Signer participants to be more efficient and accurate when searching with the contiguous than with the distant aid.
2. To measure the relationship between word categorization abilities and Web information search in Deaf Signers. In particular, again using the spatial contiguity principle, we expected that the demand for word categorization abilities during the Web search would be reduced when using the *contiguous* SL navigation aid compared with the *distant* aid.

Experiment 1

Design

A unifactorial within-participant design was used. The independent variable was the video-based SL navigation aid manipulated at two levels (distant and contiguous) that we will describe in the Materials section. In addition to the search tasks, the participants completed a Single-Word Association test, a Verbal Analogy Test, and a Reading Test.

Participants

Nineteen prelingual Deaf people (11 males and 8 females), users of the Spanish SL as native language, participated in this experiment. Fifteen of them were children of hearing parents, and four were children of

Deaf parents. The mean age was 25.5 years (minimum 19, maximum 32). Fifty nine percent of the sample were university graduates, and the rest had completed secondary education. The Hearing participants were students of an introductory course in psychology. The experiment was administered in groups of six to seven participants in the offices of the Andalusian Federation of Associations for the Deaf (FAAS). All participants were regular and experienced users of computers, spending between 2 and 5 hr/day navigating the Internet. An additional control group of 13 Hearing non-Signers undertook the experimental tasks (the Web search Task in the text-only version), in order to obtain a baseline for each task to compare the Deaf Signers' performance.

Materials

We designed a Web search task and two Web sites simulating real commercial Web sites in order to measure search performance. Categorical knowledge and processing were measured by means of the Spanish adaptations of two tests, the Single-Word Association test (McEvoy, Marschark, & Nelson, 1999) and the Verbal Analogy Test (Marschark et al., 2004), used in previous studies to assess these variables. Finally, reading comprehension was measured by means of the Reading comprehension and Inference Test of Elosúa, García-Madruga, Gárate, Gutiérrez, and Luque (1993).

Web search task. Participants were asked to buy 18 items in each of two different Web contents: entertainment and supermarket. The search time limit was 1 min per item or target. All search trials started from the home page and finished when participants clicked on a "Buy" icon close to the items.

In order to build the categories for each type of contents, the Spanish database of Marful, Fernández, and Díez (2006) was used. As can be appreciated in Figures 1 and 2 (see also supplementary material), nine categories were extracted from the database to compose the upper horizontal menu of each Web site. Each of the nine categories had six subcategories, which were displayed in the body of the Web page when participants clicked on the main category (see categories and subcategories for each Web site in Appendix Table A1).

Both Web sites were combined with the two versions of video-based SL navigation aids: distant and contiguous. As we said before, both aids consisted of videos embedded in small Web areas that contained SL translation (performed by human signers) of each text hyperlink of the menu. In the distant condition (Figure 1 and supplementary material), SL videos were always displayed in the same area, located in the bottom left corner of the screen. In the contiguous condition (Figure 2 and supplementary material), there was a small video area for each text hyperlink so that the video and text hyperlinks were spatially adjacent (one next to the other). In addition, the videos in this version were clickable; that is, they were hyperlinks themselves. The videos were activated by clicking or passing the cursor over them. A text-only version of the Web sites was created for the Hearing control group.

In order to create the videos in SL, experts from the FAAS translated the text hyperlinks into Spanish SL. An expert signer was recorded signing each term in a professional studio, and the resulting videos were edited and included in the distant and contiguous Web sites by the Web designers of the company Signocom Producciones.

The order of Web site presentation and the combination of content/format was balanced between groups. The order of presentation of the 18 targets per Web site was randomized. The E-Web tool (López, 2004) was used to administer the search task and manage the counterbalancing and randomization of stimulus presentation.

The dependent variables were the mean percentage of correct answers and disorientation. As stated above, disorientation occurs when users "lose their sense of location and direction in a nonlinear document" (Utting & Yankelovitch, 1989, p. 58). In this study, disorientation was measured by means of the mean number of pages visited before finding the target; the more pages visited, the greater the disorientation.

Single-Word Association Test. This test was used to measure how participants organized their knowledge about word categories and their members or

exemplars. They had to write down the first word that came to their mind for each of a list of 40 words obtained from the Marful et al. (2006) database. Twenty of these were category names (superordinate terms) and 20 were exemplar names (subordinate terms; see Appendix Table A2). This task was a paper-and-pencil task. Three word presentation orders were created and balanced across participants.

The results of this task were calculated by item (word). The measures were the following: the strength of association for the primary associate given to each stimulus word (the primary associate was the response given by the largest portion of the individuals within a group and thus its associative strength results from dividing its frequency by the number of valid answers per item) and the number of unique answers per item, that is, those answers that only one participant gave and the number of blank answers per item. For instance, the primary associate of "animal" was "dog" because it was the word most frequently written down by Deaf participants (11 of 19). Its associative strength was 0.61, a value that results from dividing 11 by 18 (the number of participants who gave a valid answer—blank answers or no answers were considered nonvalid answers).

Verbal Analogy Test. This test was used to measure the application of categorical knowledge. Fifty-four verbal logic analogies were constructed, each one with four alternative answers (see Appendix Table A3). Following Marschark et al. (2004) and Deese (1966), the verbal analogies followed the scheme: A is to B what C is to…. We included three types of analogies: superordinates, subordinates, and coordinates.

- Superordinate analogies: participants were asked to generate a category name in answer to an exemplar name, for instance, waltz is to dance as gun is to weapon.
- Subordinate analogies: participants have to generate an exemplar name for a category name, for instance, metal is to iron as sport is to tennis.
- Coordinate analogies: participants have to find a relationship between exemplars generating an exemplar name in answer to another exemplar name, for example, foot is to hand as piano is to guitar.

The percentage of correct answers per analogy type was measured. The task was programmed in Java and presented using a Web interface.

Reading Test. Reading Comprehension abilities have been shown to be predictive of Web search performance in previous studies with Deaf Signers (Fajardo, Cañas, Salmerón, and Abascal, 2009) and, in addition, this variable usually presents a high variability within the deaf population. Therefore, we decided to measure this factor as an additional measure by means of the Reading Comprehension and Inference Test of Elosúa et al. (1993). The test was composed of four texts, each composed of three sentences presented separately. Once participants had read a complete text, one question asking about the relationship between the three sentences was presented. Each question had three answer choices, only one of which was correct. The task was administered by means of a program implemented in Java. The program randomized the order of presentation of texts and answer choices per participant. The dependent variable was the percentage of correct answers.

Procedure

For the Deaf Signers group, the experiment, which lasted 1 hour in total, was administered in two blocks. Before each block, general instructions were given in text and SL. Block 1 consisted of a Web search task, the Verbal Analogy Tasks, and Word Association Test. Block 2 consisted of reading and a personal data questionnaire. The order of the Block 1 tasks was randomized by the administration program (E-Web).

Regarding the search task, the type of Web site (supermarket and entertainment) was combined with the navigation aid (distant and contiguous) and counterbalanced between groups. Therefore, half of the participants performed the search tasks for the entertainment/distant and supermarket/contiguous conditions and the other half performed the searches for the entertainment/contiguous and supermarket/distant conditions. The participants were assigned to one of the experimental conditions in order of arrival at the experiment location. Participant 1 was assigned to Condition 1, Participant 2 to Condition 2, Participant 3 to Condition 1, and so on.

Before the 18 experimental trials per Web site, the participants performed two practice trials in order to familiarize themselves with the navigation aids and the procedure. The procedure for each search trial was as follows: The item to be purchased was presented in both text and SL in an independent window (see Figure 3). The participants had no time limit for reading the text and playing the video with the target explained in SL. Once they had clicked on "start trial," at the bottom, this window was minimized and the home page of the corresponding condition appeared. Then the participants started the search. For instance, the optimal path to find "football" consists of three hyperlinks clicked: sports, then football, and then the shopping cart for football. Finally, the participants received feedback in both text and SL, indicating whether the selection was correct or not and then the next target was presented.

For the Hearing group, the procedure was identical to that for the Deaf group except for the type of Web sites to navigate and the instruction format (oral and written).

Results of Experiment 1

Effect of type of navigation aid based on SL videos. For the Deaf Signers group, we performed an analysis of variance (ANOVA) with navigation aid as repeated measure for each dependent variable. As can be seen in Table 1, the effect of the navigation aid was not significant for any of the dependent variables: target found and pages visited. That is, Deaf Signers were similarly efficient in searching for information in both the contiguous and distant conditions.

Although the navigation aid was different, we also compared the search performance of Deaf Signers and

Figure 3 The search targets were presented in text and sign language format on a separate page, which was minimized after users clicked on "Continue" and could be accessed by users during the search.

Table 1 Deaf Signers' scores in the search task using each type of navigation aid in Experiments 1 and 2

		Experiment 1					
		Contiguous		Distant			
Deaf sign users group	*n*	*M*	*SD*	*M*	*SD*	*F*	*p*
Targets found (%)	19	83.85	23.84	86.88	21.18	0.82	.38
Pages visited	19	6.18	12.55	6.21	11.58	0.01	.92
				Text only			
Hearing group	*n*			M	*SD*		
Targets found (%)	13			100	0		
Pages visited	13			3.5	0.4		
		Experiment 2					
		Contiguous		Text only			
Deaf sign users group	*n*	*M*	*SD*	*M*	*SD*	*F*	*p*
Targets found (%)	23	77	24	82	20.7	0.74	.4
Pages visited	23	4.1	0.7	4.4	1	6.52	.02
Hearing group	*n*			*M*	*SD*		
Targets found (%)	21			96.6	2		
Pages visited	21			4.4	0.2		

the Hearing control group who performed the search task with a text-only version of the Web (see means and standard deviations in Table 1). The percentage of targets found was significantly higher for the Hearing (100%) than for the Deaf participants in both the distant (87%) and the contiguous condition (84%), $F(1, 30) = 4.94$, $MSE = 269.3$, $p < .034$. The difference between groups was not significant in the case of number of pages visited ($M_{\text{Hearing group}} = 3.5$).

Single-Word Association test. Table 2 shows the mean scores for each type of measure in this test. We performed an ANOVA by item with Type of User as an independent intraitem variable (Deaf Signer vs. Hearing non-Signer participants) and type of stimulus as a variable between items (exemplar vs. category). The only significant effect was the effect of type of stimulus for unique answers, $F(1, 38) = 7.23$, $MSE = 4.7$, $p < .011$, where category names ($M = 3.8$) obtained a lower mean for unique answers than exemplar names ($M = 5.5$); that is, for both Hearing and Deaf participants, category representations seem to be more homogeneous among participants than exemplar representations.

Additional analyses showed that 23 of 40 first associates of Deaf participants match the primary associates of Hearing participants. In addition, in the Hearing group, 31 of 40 primary associates had an associative strength equal or superior to 0.5 (16 for categories and 15 for exemplars), whereas in the Deaf Signers group, only 26 primary associates presented an associative strength equal or superior to 0.5 (12 for categories and 14 for exemplars). This means that although there was a high number of primary associate matches between the groups of participants, the associate strength for Deaf Signer participants was lower than that for Hearing participants.

Verbal Analogy Test. We performed an ANOVA with analogy type (superordinate, subordinate, and coordinate analogy) as the within-participant variable and user type as the between-group variable. The percentage of correct analogies solved was introduced as a dependent variable. Means and standard deviations for each condition can be seen in Table 3. The main effect of analogy type was significant, $F(2, 60) = 90.04$, $MSE = 0.03$, $p < .001$. In particular, participants solved more subordinate analogies ($M = .95$, $SD = 0.09$), followed by superordinate ($M = .9$, $SD = 0.12$) and coordinate analogies ($M = .4$, $SD = .35$). The main effect of participant type was also significant, $F(1, 30) = 20.84$, $MSE = 0.04$, $p < .001$. Deaf participants ($M = .67$, $SD = 1.1$) solved fewer analogies than Hearing participants ($M = .86$, $SD = 1.0$).

The interaction between user type and analogy type was also significant, $F(2, 60) = 14.07$, $MSE = 0.03$, $p < .01$. In particular, the difference between participant groups was significant for coordinate analogies, $F(1, 30) = 21.15$, $MSE = 0.07$, $p < .001$, but not for subordinate analogies, $F(1, 30) = 1.94$, $MSE = 0.01$, $p = .175$, or superordinate analogies,

Table 2 Mean scores (percentage of correct answers) of deaf and hearing participants for each type of measure of the single-word association test in Experiment 1

	Stimulus					
	Category		Exemplar		Total	
	Deaf participants					
Measures	*M*	*SD*	*M*	*SD*	*M*	*SD*
Associative strength	.52	0.14	.61	0.24	.56	0.20
Unique answers	4	3.26	5.4	2.11	4.7	2.80
No answer or blanks	.55	1.05	.3	0.92	.42	0.17
	Hearing participants					
	M	*SD*	*M*	*SD*	*M*	*SD*
Associative strength	.60	0.18	.63	0.25	.62	0.22
Unique answers	3.55	2.32	5.55	2.13	4.55	2.44
No answer or blanks	0	—	0	—	0	—

$F(1, 30) = 3.27$, $MSE = .0139$, $p < .08$. Additionally, Deaf participants solved more subordinate than superordinate analogies, $F(1, 30) = 9.86$, $MSE = 0.004$, $p < .003$. This difference was not significant in Hearing participants, $F(1, 30) = 1.83$, $MSE = 0.004$, $p = .18$.

Correlation between analogy, reading comprehension, and Web search tasks. Our goal was to measure the relationship between word categorization abilities and Web information search. In particular, for the Deaf Signers group we expected an absence of correlation between Web search performance and Deaf Signers' word categorical abilities if the contiguous SL cues facilitated access to categorical knowledge. In order to measure the relationship between these two variables, we performed a Pearson's correlation analysis for each type of video-based SL navigation condition (distant and contiguous) between the percentage of correct answers and number of pages visited in the search task, on the one hand, and the percentage of correct answers in each analogy subtype of and reading test, on the other hand (for Deaf Signer participants only).

As we can observe in Table 4, in the distant condition there were significant negative correlations between the superordinate and subordinate correct analogies and the number of pages visited in the search task; the more correct answers in superordinate and subordinate analogies, the fewer the number of pages visited in the search task. The negative correlation between the number of pages visited and percentage of correct answers in the reading test (mean average of correct inferences = .75, $SD = 0.22$) was also significant. The higher the reading test performance, the fewer the number of pages visited by participants to find the targets.

Table 3 Mean scores (percentage of correct answers) of deaf and hearing participants for each analogy type in Experiments 1 and 2

	Experiment 1			
	Deaf Signers ($n = 19$)		Hearing ($n = 13$)	
Type of analogy	*M*	*SD*	*M*	*SD*
Superodinate	.87	0.1	.95	0.06
Subordinate	.94	0.1	.98	0.03
Coordinate	.22	0.3	.67	0.3
	Experiment 2			
	Deaf Signers ($n = 23$)		Hearing ($n = 21$)	
	M	*SD*	*M*	*SD*
Superodinate	.86	0.1	.96	0.05
Subordinate	.91	0.1	.99	0.03
Coordinate	.32	0.2	.72	0.3

Table 4 Results of correlation analyses between Web search measures and the analogy test and reading measures for Deaf and Hearing participants in Experiment 1

	Hearing control group (n = 13)			Deaf Signers group (n = 19)					
	Text-only condition			Distant condition			Contiguous condition		
Variables	r	$t(N-2)$	p	r	$t(N-2)$	p	r	$t(N-2)$	p
Superordinate/targets found (%)	—	—	—	.25	1.06	.30	−.03	−0.11	.91
Superordinate/pages visited	**−.53**	**−2.06**	**.06**	**−.64**	**−3.40**	**.00**	.05	0.22	.83
Subordinate/targets found (%)	—	—	—	.41	1.85	.08	.14	0.60	.56
Subordinate/pages visited	**−.60**	**−2.50**	**.03**	**−.57**	**−2.89**	**.01**	−.14	−0.57	.58
Coordinate/targets found (%)	—	—	—	.00	0.02	.99	−.02	−0.08	.94
Coordinate/pages visited	−.15	−0.50	.63	.18	0.76	.46	.02	0.08	.94
Reading accuracy/targets found (%)	—	—	—	.14	0.61	.54	.12	0.51	.61
Reading accuracy/pages visited	.20	0.68	.51	**−.45**	**−2.09**	**.05**	−.29	−1.25	.22

Note. Values in bold represent statistically significant results.

However, for the contiguous condition, there were no significant correlations between the search performance and the analogy or reading test performances.

Pearson's correlation was performed for the Hearing control group for the text-only condition. Results showed significant and close-to-significant (p = .06) negative correlations between correct subordinate and superordinate analogies and the number of pages visited (see Table 4). Again, the more correct answers in the superordinate and subordinate analogies, the fewer the number of pages visited in the search task (see Table 4). The correlation between word categorization scores and the percentage of targets found was not performed because of the absence of variability in the later measure for the Hearing control group.

Discussion of Experiment 1

The objective of Experiment 1 was twofold: (a) to compare the efficacy of two navigation aids to support text hyperlinks based on SL videos (in terms of accuracy and disorientation) and (b) to test the hypothesis that the presence of SL cues contiguous to text hyperlinks would reduce the requirement for Deaf Signers' word categorization abilities during information search in a hierarchical Web site compared to distant cues.

Regarding the first objective, our results showed that Deaf Sign participants obtained an equivalent accuracy level using both video-based SL navigation aids (distant and contiguous). Therefore, we conclude that both systems are similar regarding efficacy; that is, the spatial contiguity principle is not fulfilled regarding Web performance.

However, and linking with the latter goal of Experiment 1, despite there being no differences in accuracy and disorientation, the results revealed that Deaf Signers' search performance was more related to their word categorization and reading comprehension abilities in the distant condition than in the contiguous one. The main difference between the distant and contiguous conditions is the spatial proximity between SL videos and text hyperlinks (higher in the contiguous condition). According to the spatial contiguity principle (Mayer, 2005), this proximity should help users to find the link between both sources of information. We expected that our manipulation of text hyperlink–SL video proximity would affect both search performance and the requirement for word categorization abilities, but, instead, it only seems to have affected the second. In the distant condition, the relationship between the text links and SL videos is not easy to retain and users rely more on the text links, having to use their verbal lexicon more than in the contiguous condition. This result leads us to the conclusion that the contiguous video-based SL navigation aid is more efficient in supporting Web information search than the distant aid because it allows users to have the same level of performance with less dependence on verbal resources.

The Hearing control group also showed a negative correlation between word categorization test performance (in the sub- and superordinate conditions) and

disorientation during the text-only Web search. This finding would serve to support the assumption that word categorization abilities are involved in Web search with text hyperlinks regardless of the hearing status of the users.

Additionally, Experiment 1 allowed us to compare Deaf Signer and Hearing non-Signer adults in their organization and use of categorical knowledge. Replicating previous findings (e.g., Marschark et al., 2004; McEvoy et al., 1999), the single-word association task revealed a higher heterogeneity among Deaf participants than among Hearing participants. However, we only found 57.7% matches between Deaf and Hearing participants' answers, which contrasts with the 77% and 88% matches found by McEvoy et al. and Marschark et al., respectively. This matching difference between our experiment and the previous ones could be due to differences between English and Spanish category names (e.g., Spanish words are longer than English ones, which seems to affect lexical access in poor readers). Some authors suggest that the structure of categorical knowledge depends on experience (Landauer & Dumais, 1997), in particular, on formal experience acquired in the educational system. Therefore, the differences between our results and previous findings could be alternatively explained by differences in educational levels between the Spanish and American samples participating in the respective experiments (e.g., 50% of university graduates in the Spanish sample vs. 100% of college students in the sample of Marschark et al.).

Finally, the Verbal Analogy Task showed that Deaf Signer participants obtained a smaller percentage of correct answers than Hearing participants, especially in the case of coordinate analogies, where the differences were significant. These results would support the hypothesis of Marschark et al. (2004), which states that the lower stability and coherence of Deaf Signers' knowledge organization would prevent them from using it efficiently in problem-solving tasks such as analogy tasks or Web search.

In summary, these results help us to select the contiguous navigation aid based on SL videos as being more efficient than the distant aid for supporting Deaf Signers' Web information search with text hyperlinks. However, we have shown that the performance of Hearing participants with this type of Web content in text format is still higher than the Deaf Signers' performance with text plus SL links (distant and contiguous). This means that the contiguous SL navigation aid might not be necessarily improving Deaf Signers' performance compared to a text-only aid. In fact, previous research has shown that the performance of deaf students using real-time text alone improved comprehension of academic lectures compared to the SL interpreting or both (e.g., Marschark et al., 2006). Therefore, the next step is to prove that a system with these characteristics can really improve the Web search performance of Deaf Signers compared to a traditional text-only hyperlink navigation aid. This was the main goal of Experiment 2. Again, we expected not only an effect on search accuracy and efficiency (number of pages visited) but a reduction of the requirement for word categorical skills when using SL cues instead of text-only cues.

Experiment 2

Design

The main goal of Experiment 2 was to compare Deaf Signers' information search with text-only hyperlinks versus text hyperlink combined with contiguous SL videos. Our hypothesis was that Deaf Signers would find more targets, visit fewer pages, and use their word categorization abilities less when using the combined text plus SL video navigation aid than the text-only version.

Therefore, we conducted a unifactorial within-participant design with type of navigation aid (text link vs. SL video link). The dependent variables were again the percentage of correct answers and number of pages visited. In addition, the participants completed the Verbal Analogy Task and the Reading Comprehension test. The Single-Word Association test was not used in this experiment in order to reduce the length of the experimental session.

Participants

Twenty-three Deaf Signers of SL as native language (11 males and 12 females; 11 from the Basque Country

Federation of Associations for the Deaf and 12 from the FAAS) and 21 Hearing people (14 females and 7 males) participated in this study in exchange for monetary compensation or course credits. The mean age of the Deaf group was 31.78 years (minimum 17, maximum 50), and the mean age of the Hearing the group was 21.76 years (minimum 17, maximum 35). Of the Deaf sample, 45% were university graduates and the rest had completed secondary education. The Hearing participants were students of an introductory course in psychology. The participants in Experiments 1 and 2 were different. However, Deaf Signers groups were comparable in mean age (mean age in Experiment 1 was 25.5), type of deafness (prelingual), and mother tongue (SL). In addition, all of them belonged to Basque or Andalusian Deaf associations, which means that they belonged to the Deaf Community and had an SL educational background.

The experiment was administered in groups of six to seven participants at the headquarters of the FAAS and Basque Country Federation of Associations of the Deaf; in the Hearing group, the administration of the study was on an individual basis.

Materials

With regard to the search task materials, we used the contiguous condition of Experiment 1 and a text-only version of it, which was identical to the former regarding structure and physical appearance, with the only difference being that the SL videos were removed (see Figure 4 and supplementary material). We used the same version of the text plus SL video Web site for both the Basque and Andalusian signers sample except for some SL terms that were adapted for the Basque signers sample, because there were some regional terminological differences (e.g., the sign for "shoe" was different in Basque and Andalusian SL). The control group of Hearing nonsigners only performed the search task in the text condition and the instructions were presented only in text format.

The materials for the Verbal Analogy Task and the Reading Comprehension test were identical to those in Experiment 1. The Experiment was administered by means of the E-Web tool, which was in charge of counterbalancing the content/navigation aid type combination and the order of presentation of tasks and search targets.

Figure 4 Page of the Web site used in the text-only condition of Experiment 2.

Results of Experiment 2

With regard to the Deaf Signers group, we performed an ANOVA with navigation aid as a repeated measure for each dependent variable. The search accuracy, as measured by the percentage of targets found, did not vary between the different types of navigation aid (see *M*s, *SD*s, and *F*s in Table 1). However, Deaf Signers visited more pages before finding the target with the text link Web site than with the text plus SL video Web site. We also analyzed the difference between Basque and Andalusian participants regarding search performance and no significant differences were found (percentage of targets found, $F(1, 21) = 0.31$, $MSE = 22.7$, $p < .586$; disorientation, $F(1, 21) = 1.61$, $MSE = 1.3$, $p < .218$).

We compared the search performance of Hearing and Deaf participants in both the Text and Video conditions. Hearing participants found a significantly higher percentage of targets than Deaf participants in both the Text condition, $F(1, 42) = 9.78$, $MSE = 7.3$, $p < .01$ (*M*s and *SD*s in Table 1), and Video condition, $F(1, 42) = 12.7$, $MSE = 9$, $p < .01$. However, Hearing participants got more disorientated in the Text condition than Deaf participants did in the Video condition, $F(1, 42) = 4.64$, $MSE = 0.3$, $p < .037$. There were no significant differences in disorientation between the groups of participants when both searched in the Web sites with text-only links ($M = 4.4$ for both types of users), $F(1, 42) = 0.001$, $MSE = 0.6$, $p < .985$.

Regarding the verbal analogy test (see *M*s and *SD*s in Table 3), results showed that Deaf Signers ($M = .7$, $SD = 1.2$) resolved a lower percentage of verbal analogies than Hearing participants ($M = .9$, $SD = 1.1$), $F(1, 42) = 30$, $MSE = 0.04$, $p < .001$, a difference which resulted in significance for the three types of analogies: superordinate, $F(1, 42) = 13.8$, $MSE = 0.01$, $p < .001$; subordinate, $F(1, 42) = 8.22$, $MSE = 0.01$, $p < .001$; and coordinate, $F(1, 42) = 25$, $MSE = 0.01$, $p < .001$.

Finally, for Deaf Signers, we performed several Pearson's correlation analyses between each subtest of the verbal analogy task and the search measures. The results showed a positive significant correlation between the percentage of correct searches and number of subordinate analogies resolved for both video and text-only conditions (see Table 5 for *R*s and *p* levels).

However, in the case of number of pages visited, the correlation, negative in these cases, appeared only in the case of the text link condition (significant for pages visited). These results were again interpreted as a support to our second hypothesis; that is, text hyperlinks combined with SL reduce the requirement for word categorization abilities. We repeated the analyses of correlation for Hearing participants, and no significant effects were found.

General Discussion

How Web users draw on nontext information cues and the differences between text and nontext cues when searching are both underresearched topics. The main goal of the presented research was to test the efficacy of SL videos as hyperlinks to improve Web search for Deaf Signers. In particular, we hypothesized that SL videos would produce two effects: (a) improving search efficacy and efficiency (increasing accuracy and lessening disorientation) and (b) reducing the involvement of word categorization abilities during Web search. We have found support for the improvement in Web search efficiency (disorientation) and a reduction of the need to use verbal abilities, in particular, word categorization abilities. These results have important theoretical and practical implications.

From a theoretical point of view, Experiment 1 shows that the use of word categorization abilities is related to Hearing participants' Web search performance, which is one of the assumptions based on which we started to demonstrate the facilitative effect of the SL navigation aids (distant vs. contiguous) on Web search. For the Hearing group, the higher the categorization abilities, the less the disorientation in the Web search task with text-only links. This effect is replicated for the Deaf Signers group, but only in the distant condition, whereas the search accuracy (percentage of targets found) remains constant between conditions (distant and contiguous), which is interpreted as a facilitative effect of the contiguous

Table 5 Results of correlation analyses between Web search measures and the analogy test and reading measures for Deaf and Hearing participants in Experiment 2

	Hearing control group ($n = 21$)			Deaf Signers group ($n = 23$)					
	Text-only condition			Text-only condition			Contiguous condition		
Variables	r	$t(N-2)$	p	r	$t(N-2)$	p	r	$t(N-2)$	p
Superordinate/targets found (%)	.21	0.93	.36	.28	1.35	.19	.29	1.39	.17
Superordinate/pages visited	.10	0.42	.68	−.16	−0.75	.46	−.29	−1.39	.18
Subordinate/targets found (%)	−.23	−1.03	.31	**.59**	**3.32**	**.01**	**.40**	**2**	**.058**
Subordinate/pages visited	−.30	−1.37	.19	**−.42**	**−2.1**	**.05**	−.28	−1.33	.2
Coordinate/targets found (%)	−.12	−0.54	.59	.25	1.2	.24	.31	1.52	.14
Coordinate/pages visited	.21	0.93	.36	−.05	−.21	.84	.11	0.52	.6
Reading accuracy/targets found (%)	.10	0.42	.68	.31	1.51	.14	−.27	−1.27	.22
Reading accuracy/pages visited	−.23	−1.03	.31	.04	0.17	.46	−.26	−1.24	.22

Note. Values in bold represent statistically significant results.

condition (less use of word categorization abilities). However, this relation is not replicated for Hearing participants in Experiment 2. A possible explanation is the low variability in both verbal analogy correct answers and search disorientation (the *SD*s were 1.1 and 0.2, respectively). This problem must be studied in depth in future research by designing Web contents of higher complexity for Hearing participants or selecting a sample with higher variability. In spite of this methodological limitation, the results for the Deaf Signers group are of intrinsic value. Replicating previous findings (Marschark et al., 2004), we find that Deaf Signers' word categorization abilities are lower than those for Hearing participants (Experiments 1 and 2), so that it would be desirable to reduce its use for Web searching. In effect, as the results of Experiments 1 and 2 show, Deaf Signers are not only less disoriented when searching in the contiguous video condition but also make less use of their word categorization abilities than in the distant and text-only conditions. We have argued that the contiguous condition facilitation could be based on the adjustment to the spatial contiguity principle, that is, video-text proximity in this condition could help to find the relation between both sources of information, helping Deaf Signers to interpret text links' meaning.

The facilitative effect of SL navigation aid is even more relevant if it is contrasted with previous findings showing the opposite effect, that is, facilitative effect of printed text versus SL for Deaf Signers. Although SL can convey complex information, it might not be as effective to facilitate the comprehension of academic information for Deaf students (e.g., Marschark et al., 2006; Rodriguez-Ortiz, 2007b) as oral languages are for hearing students. For instance, Marschark et al. (2006) compared the effect of comprehension of an academic lecture by Deaf Sign students using real-time text transcriptions, SL interpreting, and both. They found that real-time text alone improved the performance of deaf students significantly compared to the other two conditions. Rodriguez-Ortiz has found that Deaf Signers extracted less information than hearing signers from signed lectures. This author suggests the differences in discourse-processing strategies as a possible explanation for the difference between Hearing and Deaf people, as well as less language exposure during childhood and later acquisition of spoken language, which could determine the acquisition of metacomprehension abilities (for a further discussion on this topic, see Fajardo, Vigo, & Salmerón, 2009). Differences in metacognition could be also on the origin of deaf and hearing differences in the verbal analogy test found in Experiments 1 and 2. According to Marschark et al. (2004), the Deaf Signers' lack of task-related strategies such as finding relations across items and metarelations between pairs of items (necessary to solve verbal analogies) might underlie the difference between Deaf and Hearing individuals in higher order tasks such as verbal analogy task or Web search.

A methodological limitation related to our findings is that we use a correlational approach to test the hypothesis about the relation between word categorization abilities and search performance, which means that we cannot establish cause–effect relationships between these variables. A third variable such as verbal memory span, spatial span, or episodic memory could be covariating with word categorization abilities, better explaining the effects. In fact, previous studies have shown that Deaf people usually show a lower verbal memory span (the amount of information we can retain in short-term memory) than hearing people (e.g., Chincotta & Chincotta, 1996; Flaherty, 2000; Logan, Maybery, & Fletcher, 1996). Therefore, differences in verbal span could potentially be a factor in explaining the differences in the hypertext tasks between Deaf and Hearing participants. However, as was found in a previous study (Fajardo et al., 2008), Deaf Signers' verbal span does not seem to correlate significantly with Web search performance (with text-only links). The hierarchy of Web content used in Fajardo et al. was simpler than that used in this article though, which could explain the absence of verbal span–search correlation in the former. Other variables that could be related to the search performance of Deaf Signers could be their educational background or visual ability, but we did not manipulate these in our experiments. All these issues are open questions for future research that could not be explored in this study due to time limitation.

From a practical point of view, our findings support the idea that the inclusion of SL on the Web by means of a video-based navigation aid may effectively improve the access to knowledge and education for Deaf Signers; that is, the provision of search cues in SL, the native language of Deaf Signers, improves Web information search for this type of user. However, the video-based SL navigation aid must be designed in such a way that the SL video cue can be clearly identified, for example, by means of the spatial contiguity between design elements. This design effect is actually what Experiment 1 shows; that is, the spatial contiguity between the SL videos and text hyperlinks is able to reduce the Deaf Signers' use of word categorization abilities, which can be lower in Deaf than in Hearing individuals.

It is important to note that we are not recommending the use of the SL video technology we used in our experiment. Instead, we are highlighting the importance of using SL cues and a way of combining both SL and text cues in order to augment their efficiency. As we said in the Introduction, technology grows very fast and there are other options existing to convey SL on the Web that could be more efficient than videos from a technological point of view. For instance, other approaches like the avatar technology (*e-Sign*; Kennaway, Glauert, & Zwitserlood, 2007), allows the conveyance of SL on the Web while removing the necessity of using large video files that may slow down the loading and rendering processes.

Without ignoring considerations for other applications and environments, our overall results do represent an empirical support for the usage of SL cues (videos in this case) linked to text hyperlinks as an efficient Web navigation aid for Deaf Signers. Our hypothesis is that the requirement for word categorization abilities is reduced in the SL video condition because the presence of SL cues allows Deaf Signer participants to use an SL code instead of a verbal one to access their categorical knowledge stored in long-term memory more easily. How Deaf Signers actually use and combine the information contained in SL videos and text hyperlinks in order to assess the similarity between searching goals and hyperlink choices still cannot be drawn from our results. The answer to this question could serve Web information search models to explain the following of nontext information cues.

Supplementary material

A supplementary section is located with the electronic version of this article at Journal of Deaf Studies and Deaf Education online (http://jdsde.oxfordjournals.org/).

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Appendix A

Table A1 Categories and subcategories of items composing the supermarket and entertainment Web sites (in Spanish in the experiments)

Web "supermarket"	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6
Alcoholic drinks	Whiskey	Rum	Wine	Liquor	Martini	Tequila
Nonalcoholic drinks	Water	Juice	Coca-cola	Milk	Shake	Coffee
Condiments	Salt	Piper	Oregano	Garlic	Vinegar	Paprika
Flowers	Rose	Daisy	Carnation	Flower of purple	Christmas flowers	Aromatic flowers
Fruits	Apple	Pear	Orange	Plum	Peach	Mandarin
Garments	Trousers	T-shirt	Skirt	Panties	Scarf	Shorts
Types of shoes, clogs	Boots	Sandals	Shoe	Clog	Sports shoe	Ski boots
Cookware	Pan	Spoon	Knife	Dish	Pot	Ladle
Vegetables	Salad	Cauliflower	Spinach	Tomato	Carrot	Leek
"Leisure and culture" Web	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6
Weapons	Pistol	Shotgun	Knife	Machine gun	Cannon	Rifle
Dances	Tango	Salsa	Belly dance	Dance	Jazz	Flamenco
Sports	Football	Basketball	Tennis	Volleyball	Rugby	Cycling
Tools	Drill	Screw	Clamps	Hammer	Screwdriver	Adjustable wrench
Musical instruments	Guitar	Flute	Violin	Drum	Viola	Bass
Toys	Doll	Car	Ball	Football	Puzzle	Barbie
Reading materials	Book	Magazine	Newspaper	Novel	Encyclopedia	Tale
Types of music	Rock	Opera	Classic	Jazz	Heavy	Hip hop
Vehicles	Car	Motorcycle	Truck	Formula 1	Boat	Tractor

Appendix B

Table A2 List of names used in the single-word association task (in Spanish in the experiments)

Category names
Weapon, dance, alcoholic drink, sport, flower, fruit, animal, combustible, type of criminal act, alcoholic drink, disease, tool, metal, clerk, relatives, part of a building, condiments, precious stone, snakes, boats.
Exemplar names
Guitar, toll, book, rock, bouts, car, mountain, chemistry, euro, verb, rain, pan, fly, trousers, table, Spain, lettuce, toe, trout, psychologist.

Appendix C

Table A3 Analogies used in the Verbal Analogy Test (in Spanish in the experiments)

Vals es a baile lo que pistola es a: Ciencia, arma, dinero, árbol
Waltz is to dance as pistol is to: science, gun, money, tree
Vehículo es a coche lo que arma es a: Mosca, Montaña, Escopeta, Perro
Vehicle is to car as weapon is to: fly, mountain, shotgun, dog
Avión es a helicóptero lo que cuchillo es: robo, Euro, Navaja, Padre
Airplane is to helicopter as knife is to: theft, Euro, razor, father
Águila es a ave lo que salsa es a: accidentes geográficos, Vehículo, Verduras, Bailes
Eagle is to bird as salsa is to: geographic features, vehicle, vegetables, dances
Cargo político es a presidente lo que baile es a: Perro, Montaña, Coliflor, Jota
Political position is to president as dance is to: dog, mountain, cauliflower, jota dance
Mosca es a hormiga lo que tango es a: Cerveza, Tortilla, Avión, Sevillanas
Ant is to fly as tango is to: beer, omelet, airplane, sevillanas (flamenco-style dance)
Química es a ciencias lo que vino es a: bebida alcohólica, Vehículo, Aves, Animales de 4 patas
Chemistry is to science as wine is to: drink, vehicle, birds, 4-legged animals

Table A3 Continued

Insecto es a avispa lo que bebida alcohólica es a: agua, Cebolla, Whisky, Mesa
Insect is to wasp as drink is to: water, onion, whiskey, table
Taza es a tenedor lo que ron es a: cigarro, Coche, Barco, Cerveza
Cup is to fork as rum is to: cigar, car, boat, beer
Novela es a material de lectura lo que agua es a: ciencias, Deportes, Partes de un edificio, Bebidas no alcohólicas
Novel is to reading materials as water is to: science, sports, parts of a building, nonalcoholic drinks
Flor es a rosa lo que bebida no alcohólica es a: plato, Lápiz, Zumo, Gato
Flower is to rose as nonalcoholic beverage is to: plate, pencil, juice, cat
Papel es a bolígrafo lo que coca-cola es a: cenicero, Leche, Libro, Moto
Paper sheet is to pen as coca-cola is to: ashtray, milk, book, motorcycle
Pedro es a nombre de varón lo que pimienta es a: vehículo, Clero, Condimentos, Partes del cuerpo
Peter is to male first name as pepper is to: vehicle, clergy, condiments, body parts
Combustible es a gasolina lo que condimento es a: orégano, Abogado, Lápiz, Sartén
Fuel is to gasoline as condiment is to: oregano, lawyer, pencil, skillet
Hormiga es a mosca lo que sal a: cigarro, cara, perejil, tijeras
Ant is to fly as salt is to: cigar, face, parsley, scissors
Robo es a delito lo que tenis es a: colores, Muebles, Deportes, Aves
Stealing is to crime as tennis is to: colors, furniture, sports, birds
Metal es a hierro lo que deporte es a: España, Martillo, Fútbol, Mesa
Iron is to metal as sport is to: Spain, hammer, soccer, table
Piano es a guitarra lo que baloncesto es a: natación, Gato, Pie, Patata
Piano is to guitar as basketball is to: swimming, cat, foot, potato
Violín es a instrumento musical lo que martillo es a: metales, Parientes, Edificios, herramientas
Violin is to musical instrument as hammer is to: metals, relatives, buildings, tools
Embarcación es a yate lo que herramientas es a: mesa, destornillador, Portugal, Tuerca
Boat is to yacht as tools is to: table, screwdriver, Portugal, nut
Silla es a sillón lo que alicates es a: llave inglesa, Iglesia, Robo, Hermano
Chair is to armchair as pliers is to: adjustable wrench, church, robbery, brother
Lluvia es a fenómeno atmosférico lo que margarita es a: verduras, Instrumento musical, Flores, Aves
Rain is to atmospheric phenomenon as daisy is to: vegetables, musical instrument, flowers, birds
País es a Suiza lo que flor es a: piano, Martillo, Clavel, Turquesa
Country is to Switzerland as flower is to: piano, hammer, carnation, turquoise
Diamante es a perla lo que rosa es a: amapola, Alicates, Salamanca, Azul
Diamond is to pearl as rose is to: poppy, pliers, Salamanca, blue
Azúcar es a condimento lo que naranja es a: herramientas, Delitos, Frutas, Vehículos
Sugar is to condiment as orange is to: tools, crimes, fruits, vehicles
Metal es a hierro lo que fruta es a: coche, Mano, Manzana, Crisantemo
Iron is to metal as fruit is to: car, hand, apple, chrysanthemum
Vals es a salsa lo que pera es a: plátano, Verde, Gorrión, Pimiento
Waltz is to salsa as pear is to: banana, green, sparrow, pepper
Lluvia es a fenómeno atmosférico lo que guitarra es a: vehículo, Cargo político, Instrumento musical, Colores
Rain is to atmospheric phenomenon as guitar is to: vehicle, political positions, musical instrument, colors
Mueble es a silla lo que instrumento musical es a: amarillo, Clavel, Papel, Flauta
Furniture is to chair as musical instrument is to: yellow, carnation, paper, flute
Pie es a mano lo que piano es a: mesa, Caballo, Violín, Taza
Foot is to hand as piano is to: table, horse, violin, cup
Asesinato es a delito lo que coche es a: flor, Verdura, Juguete, Instrumentos musicales
Murder is to crime as car is to: flower, vegetable, toys, musical instruments
Bebida es a agua lo que juguete es a: pelota, Metano, Céntimo, Folio
Drink is to water as toy is to: ball, methane, penny, sheet
Iglesia es a ermita lo que muñeca es a: ron, Tenis, Balón, Carpeta
Church is to shrine as doll is to: rum, tennis, ball, folder
Hierro es a metal lo que periódico es a: colores, Herramientas, Material de lectura, Instrumento musical
Iron is to metal as newspaper is to: colors, tools, reading materials, musical instrument
Pariente es a madre lo que material de lectura a: cenicero, Piano, Cádiz, Libro
Relative is to mother as reading materials is to: ashtray, piano, Cadiz, book

Table A3 Continued

Casa es a piso lo que revista es a: novela, Taza, Plátano, Perro
House is to home as magazine is to: novel, cup, banana, dog
Ana es a nombre lo que pantalón es a: delitos, Cargos políticos, Prendas de vestir, Herramientas
Ana is to first names as pair of trousers is to: crime, political positions, clothing, tools
País es a Turquía lo que prendas de vestir es a: fútbol, Pedro, Cigarro, Camiseta
Turkey is to country as clothing is to: football, Peter, cigar, T-shirt
Tenis es a voleibol lo que falda es a: camisa, Folio, Navarra, Vaso
Tennis is to volleyball as skirt is to: shirt, sheet, Navarra, glass
Sal es a condimento lo que sandalias es a: deportes, Embarcaciones, Flor, Calzado
Salt is to seasoning as sandals is to: sports, boats, flower, footwear
Pariente es a hermano lo que calzado es a: zapato, Rosa, Leche, Plato
Relative is to brother as footwear is to: shoes, rose, milk, plate
Ana es a Pedro lo que botas es a: violín, Robo, Zapatillas, Iglesia
Ana is to Peter as boots is to: violin, robbery, slippers, church
Guitarra es a instrumentos musicales lo que clásica es a: tipos de música, Delitos, Partes del cuerpo, Parientes
Guitar is to musical instruments as classical music is to: types of music, crimes, body parts, relatives
Ave es a canario lo que tipo de música es a: madre, Baloncesto, Naranja, Rock
Bird is to canary as kind of music is to: mother, basketball, orange, rock
Mesa es a silla lo que pop es a: dedo, Jazz, Piano, Iglesia
Table is to chair as pop music is to: finger, jazz, piano, church
Barco es a embarcación lo que sartén es a: partes del cuerpo, Deporte, Provincias, Utensilios de cocina
Boat is to vessel as skillet is to: body parts, sport, provinces, kitchenware
Material de lectura es a revista lo que utensilios de cocina es a: mano, Sevilla, Cuchara, Salsa
Reading materials is to magazine as kitchenware is to: hand, Seville, spoon, sauce
Hierro es a cobre lo que cuchillo es a: tenedor, Barco, Camión, Pluma
Iron is to copper as knife is to: fork, boat, truck, feather
Amarillo es a color lo que moto es a: deportes, Bebidas no alcohólicas, Vehículo, Juguetes
Yellow is to color as motorcycle is to: sports, nonalcoholic beverages, vehicle, toys
Mueble es a armario lo que vehículo es a: camión, Gorrión, Química, Hurto
Furniture is to cabinet as vehicle is to: truck, sparrow, chemistry, theft
Padre es a madre lo que coche es a: cortinas, Bolígrafo, Autobús, Carpeta
Father is to mother as car is to: curtains, pen, bus, folder
Tormenta es a fenómenos atmosféricos lo que espinacas es a: calzado, Aves, Insectos, Verduras
Storm is to atmospheric phenomena as spinach is to: shoes, birds, insects, vegetables
Edificios es a iglesia lo que verduras es a: faisán, Lechuga, Amapola, Pimienta
Buildings is to church as vegetables is to: pheasant, lettuce, poppy, pepper
Euro es a céntimo lo que coliflor es a: barriga, Guante, Acelgas, Segovia
Euro is to penny as cauliflower is to: belly, glove, Swiss chard, Segovia

Note

1. Information scent cues consist of images or textual hyperlinks that people use to decide whether a path is interesting during Web navigation (Fu & Pirolli, 2007).

Conflict of Interest

No conflicts of interest were reported.

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