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EMPIRICAL RESEARCH

RECHERCHE EMPIRIQUE

INFLUENCE OF VISUAL FEATURES ON THE ABILITY TO LOCATE INFORMATION ON A SCREEN: RECOMMENDATIONS FOR SENIORS

Moget, C., Frutoso, G., Galy, E., Lepicard, G., & Bonnardel, N.

Pre-print

RESUME

PROPRIETES DE SURFACE ET PERFORMANCES DE LOCALISATION D'INFORMATIONS DES SÉNIORS

L'étude qui est décrite dans cet article s'inscrit dans un projet de conception du système de télésanté et de maintien à domicile, dit HADAGIO, qui est essentiellement destiné à un public âgé. Cette étude vise à contribuer à la définition de l'ergonomie des interfaces du portail d'applications Web qui va permettre aux utilisateurs séniors d'accéder aux services proposés par ce système. Plus précisément, un objectif appliqué consistera à proposer des recommandations concernant d'une part les couleurs des icônes et des libellés lexicaux présents sur le portail, et d'autre part le niveau de détails à préconiser pour ces icônes, afin de faciliter la tâche de localisation de ces cibles sur le portail par des séniors. Après avoir présenté des hypothèses concernant le rôle de

ces éléments de surface sur les performances de localisation de cibles, nous avons donc mis en place un protocole expérimental dont la particularité est de reposer sur l'utilisation d'un dispositif d'oculométrie dans un environnement écologique (au domicile des personnes âgées). Les participants devaient localiser des cibles dans différentes modalités de couleur et de niveau de détails. Les résultats obtenus montrent que l'association d'une cible figurative avec une couleur qui lui est non congruente dégrade les performances de temps de localisation de cette cible du fait d'un nombre de distracteurs fixés avant la cible plus élevé, mais uniquement si le lien cible-couleur congruente est fort. Ces résultats ne sont pas retrouvés lors de la localisation de cibles lexicales. Par ailleurs, un niveau de détails élevé des cibles figuratives permet d'améliorer les performances de temps de localisation, du fait d'une moindre latence saccadique, mais uniquement lorsque le lien cible-couleur congruente est faible. Ces effets de la couleur et du niveau de détails des cibles figuratives seraient liés à la mise en œuvre de processus de type Top-Down lors de la tâche de localisation des cibles.

I INTRODUCTION

I.1 SOCIETAL CONTEXT OF THE STUDY

Advances in medicine and improved living conditions mean that life expectancy has greatly increased over the past century. These demographic changes have been accompanied by a huge rise in the number of dependent people and an attendant increase in demand for care and supervision of the elderly. As the healthcare sector cannot currently cope with such numbers, finding new solutions to keep older people

in their own homes for as long as possible has become a major challenge for our society (Picard, 2009). A central issue is how to offer them services similar to those available in nursing homes.

One of the most promising solutions is to exploit the opportunities offered by new information and communication technologies (NICT), and the present study was part of a project to design a new device (HADAGIO) that would allow dependents to remain at home with close monitoring plus rapid assistance and support in the event of a problem.

I.2 INDUSTRIAL OBJECTIVES OF THE STUDY

The HADAGIO system is accessible via a touchpad or computer. It offers a full range of services for older people via a web-application portal. An ergonomic approach was implemented to design the portal's screens so they were easy to use, intuitive, and aesthetically pleasing, in order to maximize acceptance of the system. This was the industrial component of our research. Furthermore, adopting a prospective ergonomics approach, the design of the portal screens was initiated upstream of the design of the artifact. Prospective analysis of the needs of older people, as part of a participatory design project involving innovative technology, is often problematic. In parallel with this research, we therefore worked on prospective analysis methods for use in participatory design targeting older individuals (Moget, Bonnardel, & Galy-Marié, 2014).

I.3 OBJECT OF STUDY

HADAGIO is mainly aimed at frail older individuals with sufficient autonomy and cognitive skills to be able to use it. We therefore chose to focus on older people in our study (aged 60 and over, according to Bailey's classification, 2004). In addition to the industrial potential, studying the specific needs of this age group regarding the use of new technologies is both socially and economically worthwhile, as it is the one that is growing the fastest in developed countries (see Dinet & Vivian, 2009, for a review).

The present study was intended to explore the influence of two visual features (i.e., color and level of detail) on the ease with which older people are able to locate icons and lexical labels on a screen. Numerous studies in the field of color psychology have highlighted the impact of colors on emotions, as well as on attention and decision making (see Bonnardel, Piolat, & Le Bigot, 2011, for a review). In the field of human-computer interaction, Bonnardel and colleagues (2011) showed that colors influence website navigation behaviors and cognitive processes when using a website. Moreover, Byrne (1993) found that a low level of detail improves icon search performances. To our knowledge, however, no study has yet tackled the role of color and the level of target detail when older people have to locate icons or labels on a screen. A further, applied aim of the present study was thus to provide recommendations about the colors and level of detail of icons, to make the task of locating information in the HADAGIO portal as easy as possible for seniors.

II INFORMATION LOCATION: CONTRIBUTIONS OF COGNITIVE PSYCHOLOGY AND NEUROSCIENCE

II.1 DEFINITION AND MODEL OF THE INFORMATION LOCATION TASK

According to Byrne and collaborators (1999), the information location task extends from the appearance of the stimulus to the point when the participant reports finding the position of the target. The target acquisition model (TAM; Zelinsky, 2008) predicts eye movements during target localization. Eye movements are particularly interesting observables to study in visual search tasks, as they reflect the cognitive processes involved in this type of task (Rayner, 1998). There are two main types of eye movements that occur sequentially during tasks requiring visual functions, such as information searching or reading. A person's gaze can either move (*saccade*) or be relatively immobile (*fixation*; Rayner, 1998). The cognitive processing of information occurs primarily during fixations (Just & Carpenter, 1984), and is virtually absent during saccades (Fuchs, 1971), whose primary function is to move the gaze to areas of the visual field that need to be analyzed.

According to TAM, this type of task can be broken down into three stages. The first is a comparison between the mental representation of the target (stored in memory) and the perception of the visual scene. This comparison generates a cognitive map (*target map*) showing activation areas. The greater the visual similarity between target and stimulus in a given area of the visual field, the more intense the activation of that area in the target map. This map is thought to depend on the current fixation and change

with new fixations during the visual exploration of the scene, because of the fovea's limited acuity. The second stage of the model is target guidance, where the position of the next fixation on the visual scene is defined by operating a geometric mean of target map activation values, so that the gaze is directed to the location in the scene with the highest activation on the target map. Because the gaze is guided toward the target, individuals do not have to explore the visual scene at random until they find the target. The gaze focuses on those areas most likely to contain the target. The third and final step of this model involves a comparison between the mental representation of the target and the fixated item. A detection threshold determines whether the fixated item is rejected or accepted as the target. If the fixated item is rejected, it is eliminated from the target map and the process goes back to the first stage of the model. This model therefore describes a top-down process, that is to say, involving the individual's knowledge about the appearance of the target to be located. This top-down process mainly occurs when a comparison is made between displayed items and a mental representation of the target in a target location task.

II.2 MENTAL KNOWLEDGE REPRESENTATION THEORIES

Mental representations are representations of the knowledge and expertise acquired by individuals during their lifetime, and are stored in long-term memory (Denis & Dubois, 1976). These mental representations allow people to process, store and retrieve information corresponding to that knowledge (Sternberg, 2007). They are conceptualized by two main theories.

According to the *propositional* theory put forward by Anderson and Bower (1937), mental representations are stored as abstract propositions, not as images or words. Authors define a *proposition* as the statement of a relationship between elements and the designation of these elements, which can be summarized by the following formula: [Relation between elements] [(topic element), (object element)] (Sternberg, 2007). Knowledge (perceived images and words) is therefore stored in memory and retrieved as a proposition, and only subsequently translated into either words or mental images, according to current needs. However, this translation is carried out in such a way that the words or mental images do not correspond exactly to the perceived elements. According to the *double coding* theory developed by Paivio (1969), mental representations stored in memory are encoded in two ways. First, they can be encoded as analogical images, and thus retain the main perceptual features of the physical stimuli or perceived objects. This coding applies to mental representations of perceived figurative images of existing objects. Second, the coding can be verbal, meaning that the information or knowledge is represented in a symbolic way, and not as it is perceived. This coding applies to mental representations of words and concepts in general.

Both these theories therefore identify two different types of knowledge entailing two different mental representation processes, each with its own format: knowledge presented in figurative versus lexical form. It therefore seems appropriate to consider icon location and word location tasks separately. Moreover, these theories predict that mental representations will incorporate visual features supplied by perceptual

information, which may include the color and level of detail of lexical or figurative targets. This point deserves to be taken further.

II.3 SPECIFIC NEEDS OF OLDER PEOPLE IN INFORMATION LOCATION TASKS

II.3. A Poorer visual search performances of older individuals

Older people perform less well than their younger counterparts on visual search tasks, being slower and less accurate. Older people are also more sensitive to factors for visual search task difficulty. For example, their performances are more impaired than those of young people when there is a large number of distractors around the target (Dennis, Scialfa, & Ho, 2004), the target and distractors are visually similar (Scialfa, Essau & Joffe, 1998), or the visual distractors are heterogeneous (Scialfa, Thomas, & Joffe, 1994).

II.3.B Preservation of top-down control

Despite the decline in seniors' visual search performances, researchers have observed age-related preservation of top-down processes during visual searching, that is, processes based on knowledge of the target's visual features (Açik, Sarwary, Schultze-Kraft, Onat, & König, 2010). Studies have shown that the visual search performances of older people, albeit poorer than those of young people, improve just as much when top-down processes are favored by the experimental conditions (Costello, Madden, Shepler, Mitroff, & Leber, 2010; see Zanto & Gazzaley, 2014, for a review). We therefore wanted to determine whether the visual features (color and

level of detail) of figurative and lexical targets could be used in an ecological environment to promote the implementation of top-down processes, and thus lead to similar levels of improvement in target location among both seniors and younger people. We also wanted to analyze the nature of these potential top-down processes using an eye-tracking device.

III METHODS

III.1 OBJECTIVES AND HYPOTHESES

The objective of the present study was to determine the roles played by level of detail for figurative targets, and by color for both figurative and lexical targets, in the implementation of top-down processes during a target location task. We formed two hypotheses. First, if figurative targets represent familiar, real-life objects, then a high level of detail will maximize the similarity between the target and the actual object, thus making it easier to use knowledge about the target's appearance in a location task. Second, if a color associated with a target is also culturally associated with the concept represented by the target, then it will be easier to use this target color knowledge to locate the figurative and lexical form of the target. If these two assumptions hold, then targets with a high level of detail, and the presence of appropriate colors associated with the target, should improve participants' performance, compared with other conditions, and this improvement should be equivalent for both young and older people.

III.2 MATERIALS

III.2.A Equipment and software

For the purposes of this experiment, we used a Dell computer with a screen size of 15 inches and a resolution of 1440 x 900, color calibrated with Spyder 4 Elite. Participants used a mouse to interact with the computer. The IT platform for the study was developed on OpenSesame software (Mathot, Schreij, & Theeuwes, 2012), in Python language. Furthermore, we chose the Tobii X1 Light eye-tracking device, which uses the pupil center corneal reflection technique to detect eye movements. The sampling rate of the Tobii X1 Light is 33 Hz, its binocular gaze precision (average of both eyes) is 0.2° of visual angle, and its binocular gaze accuracy under ideal conditions is 0.5° (persons located 65 cm from the screen and in a room with brightness of 300 lux). We chose to use this device for several reasons. First, its portability meant we could take it into the participants' homes, thus ensuring ecological conditions. Its relatively low sampling rate made it insensitive to participants' head movements, so the data collected under these conditions was of a better quality.

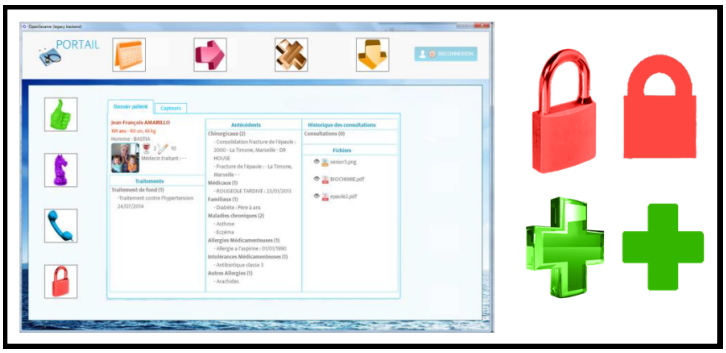
PyGaze (Dalmaijer, Mathôt, & Van der Stigchel, 2013) was used in OpenSesame to collect the eye movement data. We used a dispersion-based algorithm for fixation identification, as this type of algorithm has been shown to be reliable, robust and accurate (Salvucci & Goldberg, 2000). According Salvucci and Goldberg (2000), this algorithm is based on the fact that points belonging to the same fixation are close together (dispersion zone ranges from 0.5° to 1°, depending on the distance between

gaze and screen), owing to the low velocity of the micro eye movements that take place during a fixation and the minimum fixation duration of 100 ms (Salvucci & Goldberg, 2000). In other words, a fixation corresponds to a given minimum number of consecutive points indicating the position of the gaze (whose duration can be inferred from the sampling rate) that can be contained in a spatial area of a given size. We fixed the minimum number of consecutive points at four (corresponding to at least three intervals of 33 ms each, or 100 ms minimum), with a spatial dispersion of 1° (see Salvucci & Goldberg, 2000).

III.2.B IT Platform

The IT platform consisted of a screenshot of a HADAGIO portal page where we had defined eight positions in which the target could appear: four in the lefthand column and four along the top.

FIGURE 1: The IT platform and examples of visual stimuli with two levels of detail



To select the concepts represented by the targets, we looked for ones associated with culturally relevant colors. To this end, we conducted a survey of 120 people (60 over 60 years and 60 under 30 years), who were shown a list of HADAGIO portal concepts (e.g., open, create, health) and asked to combine each one with a color. Respondents read and signed a letter of informed consent before taking part in the survey. We retained seven concepts (see Table 1) that were significantly associated with a culturally relevant color (congruent color) by both age groups (chi-squared test). As the same color was sometimes assigned to two different concepts, we created two target lists, adding an extra item, so as to be able to present eight items in eight different colors in each trial.

Drawing inspiration from the study by Tanaka and Presnell (1999), we also determined the strength of the congruent color-concept link according to the relevance of the real-life object representing each concept. We therefore ran a second survey, this time of 20 people divided into two age groups (these participants again read and signed a letter of informed consent before taking part), who were presented with these seven concepts and asked what real-life objects they would use to represent them. People were then invited to submit as many adjectives as possible to describe the concept and the chosen object. If the color we expected was spontaneously and unanimously cited by all participants, we deemed the congruent color-concept link to be strong. If the congruent color was not spontaneously mentioned, we asked participants if one or more colors could easily be associated with this concept, and if so, why. If the congruent color was unanimously mentioned, we again deemed that the congruent color-concept

link was strong. Otherwise, we considered it to be weak. Moreover, we associated each concept with an *incongruent* color (as far as possible, the color opposite the congruent color on the color wheel), as well as with black and white (corresponding here to an absence of color). Finally, we used the items that were most frequently mentioned by participants to represent the concepts in a figurative form. Table 1 sets out the results of this survey, while Figure 1 provides two examples of stimuli to show how the targets' level of detail was visually represented.

TABLE 1: Targets and their associations with objects and colors

	Object	Congruent color (strength of link)	Incongruent color
Validate	Thumbs up	Green (strong)	Purple
Close	Padlock	Red (strong)	Green
Hobbies	Knight chesspiece	Purple (weak)	Brown
Health	Pharmacy cross	Green (strong)	Brown
Create	Quill pen tip	Blue (weak)	Red
Call	Phone handset	Blue (weak)	Red
Refuse	Palm forward	Red (strong)	Green

Lexical targets were displayed on the IT Platform in rectangles measuring 100 x 165 pixels, and figurative targets were displayed in squares measuring 100 x 100 pixels. However, the areas of interest (AOIs) taken into account for the eye-tracking device included 10 pixels on either side of the target rectangle or square, to take account of the Tobii X1 Light's gaze accuracy (0.5° visual angle).

III.3 PARTICIPANTS

12 people (4 women and 8 men) under 35 years (M = 29.17, SD = 3.64) and 12 people (8 women and 4 men) over 60 years (M = 69 50, SD = 5.35) took part in our experiment. Exclusion criteria were cognitive disorders and color vision deficits.

III.4 DEPENDENT AND INDEPENDENT VARIABLES

Independent variables were age group (young vs. old), type of color associated with the concept (congruent vs. incongruent vs. black and white), and level of detail for the figurative targets (high vs. low). We used the visual search paradigm, where reaction time is regarded as an indicator of the cost incurred by the complexity of the visual search task (Wolfe, 1994). The first dependent variable was reaction time (time between the appearance of the target on the screen and the mouse click on the target), which allowed us to gauge the difficulty of the target location task as a function of the factors we examined. For this reason, we did not consider the error rate as a dependent variable in this study. We considered the following eye-tracking indicators:

1) indicators of initial target guidance: **direction of the first saccade** (angle in degrees between the line connecting the first and second fixation points, and the line

connecting the initial fixation point to the target position; Zelinsky, 2008) and **saccadic error** of the initial saccade (pixel distance between the landing point of the first saccade and the position of the target; Williams, Reingold, Moscovitch, & Behrmann, 1997);

2) indicators of guidance during the trial: **scanpath ratio** (ratio of the sum of the amplitudes of all the saccades made during a trial to the segment connecting the point of the first fixation and the target point position; Zelinsky, 2008) and **number of distractors fixated before the target** during a trial (Yang & Zelinsky, 2009);

3) indicators of visual search efficiency: **mean number of saccades** and **mean saccadic amplitude** per trial (Goldberg & Schryver, 1995), **mean number of fixations per visited AOI** (Williams et al. 1997), **initial saccade latency** (time between appearance on screen and start of first saccade; Yang & Zelinsky, 2009) and **mean fixation duration per visited AOI** (Zelinsky, 2008).

III.5 ETHICAL PROCEDURE

When recruiting people, we gave them an information letter stating the study's objectives and operating procedures, confidentiality, the anonymization of the data collected and their intended use, and the participants' rights to ask questions, interrupt the experiment at any time, and access the data. We encouraged them to read the information letter through carefully before deciding whether or not to take part. During the experiment, we asked those who had decided to participate to sign a letter of informed consent. This reiterated the contents of the information letter. By signing, the

participants acknowledged that they had been able to ask all the questions they wanted, had obtained satisfactory answers, and were willing to take part in the experiment.

III.6 EXPERIMENTAL PROTOCOL

We used the Ishihara color vision test to check for color blindness among participants, who were then asked to answer a short questionnaire to define their demographic profile. The experimenter noted important data for the experimental conditions: brightness of the room, distance between the floor and the top of the participant's head, whether the participant wore glasses, and the color of his/her eyes. The distance between the participants' eyes and the eye tracker was routinely measured and fixed at 60 cm. Participants were instructed not to move too much during the data capture, and their distance from the eye tracker was checked several times during the experiment, in particular before each calibration. This distance was used to define the fixation identification algorithm and in particular to translate the dispersion threshold value from visual angle to pixels.

In each trial, participants had to locate one of the seven targets. First, the label corresponding to the target appeared on the screen. For figurative targets, this label was accompanied by the name of the object representing the target under its iconic shape. An OK button was placed in the center of the screen, under the description of the target. When the participant was ready, he or she pressed this button, and then had to click on the target as quickly as possible. A new target description was then displayed.

A total of nine items (seven targets plus two distractors) were displayed in the course of the experiment, in different combinations of color (black and white vs. congruent color vs. incongruent color) and type (drawing vs. word vs. photograph). Participants performed all the trials presenting the items in a given combination of features (e.g., black-and-white drawings) before passing onto the following combination (e.g., words in congruent colors).

We divided the experiment into two parts: black-and-white trials followed by color ones. In the first part, all seven targets were presented randomly in each of the eight possible positions for each type of target (drawing, word, photo), making a total of 168 tests for this part. The aim here was twofold: measure location performances when targets were displayed without an associated color, and establish whether the position of a colorless target affected performance. In the second part, the seven targets were presented in six different combinations (picture/word/picture in a congruent/incongruent color) Each combination was presented in four different positions, with two positions along the top of the screen and two positions on the lefthand side, making a total of 168 tests for this part of the experiment, too. An entire data capture session therefore included 336 target location trials in total.

IV RESULTS

To analyze the data we had collected, we ran analyses of variance (ANOVAs) with R Version 3.0.3 software (R Core Team, 2014). As target position had a significant impact on location performance for black-and-white targets, we entered this factor in

all the ANOVAs to reflect this. We performed an initial ANOVA taking all the targets into account, then conducted separate ANOVAs for targets with a strong or weak link with their congruent color. It should be noted that for each ANOVA, we only considered data for the successful trials, that is, trials where participants selected the right target. For the eye-tracking results, we excluded the data of participants who had poor quality calibrations (three older and one younger participant). Accordingly, an ANOVA including position, age group, type, color and level of detail was conducted on each of the dependent variables identified above for figurative and lexical targets that were strongly or weakly linked with their congruent color.

IV.1 RESULTS FOR FIGURATIVE TARGETS

IV.1.A. Effect of type of color

Type of color had a significant effect on mean reaction times, $F(2, 21) = 10.09$, $p < 0.001$. A Tukey test showed that reaction times were significantly longer when the targets were shown in their incongruent color ($M = 1976.1$ ms, $SD = 202.5$) rather than in their congruent one ($p < 0.001$) ($M = 1849.7$ ms, $SD = 172.6$) or in black and white ($p < 0.01$) ($M = 1881.9$ ms, $SD = 186.0$). By contrast, age did not modulate this effect of type of color on reaction times, $F(3, 19) = 0.77$, *ns*, as shown by the results in the following table:

TABLE 2: Reaction times of younger and older participants for targets according to color type

	Older		**Younger**	
	Mean reaction time (ms)	***SE***	**Mean reaction time (ms)**	***SE***
Congruent color	2281.7	254.4	1418.4	154.1
Incongruent color	2431.9	309.5	1520.2	184.4
Black and white	2303.8	283.5	1461.5	170.1

When we only considered the results of targets that had a strong link with the congruent color, the results were the same as when all the targets were considered. Type of color affected reaction times, $F(2, 21) = 8.24$, $p < 0.001$, with reaction times being the longest for items in their incongruent color (M = 2007.0 ms, SD = 211.2) (Tukey test: $p < 0.01$ when compared with congruent colors (M = 1833.9 ms, SD = 170.9), and $p < 0.05$ when compared with black-and-white targets (M = 1906.3 ms, SD = 196.7)). Age did not modulate this effect of type of color on reaction times, $F(3, 19) = 0.28$, *ns*. When we only considered targets that were weakly linked to their congruent color, we found no effect of color on reaction times, $F(2, 21) = 2.94$, *ns*. Age did not modulate this lack of color type effect on reaction times for these targets, $F(3, 19) = 2.9$, *ns*. To learn more about the origin of the effect of type of color on reaction times

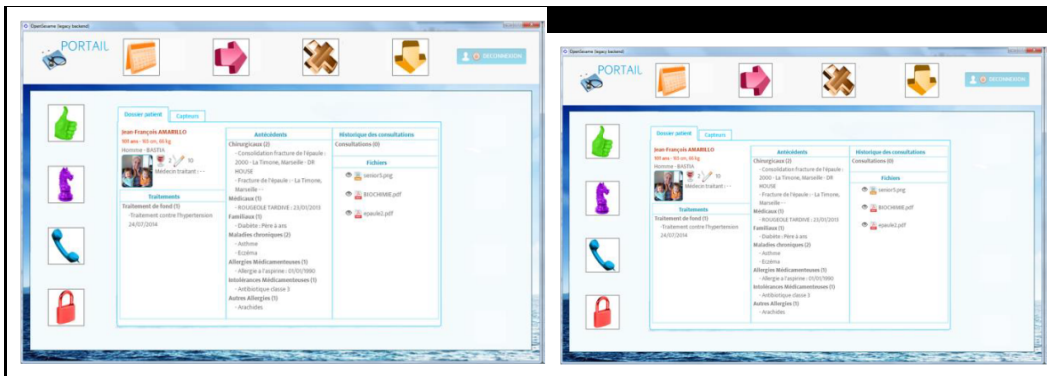
for targets strongly linked to their congruent color, we analyzed the corresponding eye-tracking data. First, the mean initial saccade latencies are shown in the following table:

TABLE 3: Mean latencies for the first saccade according to color type, for targets strongly linked to their congruent color

	Mean initial saccade latencies (ms)	***SE***
Congruent color	266.0	44.5
Incongruent color	280.9	45.7
Black and white	295.0	52.6

Results showed that color type had an effect on the number of distractors fixated before the target, $F(2, 16) = 4.78$, $p < 0.01$), with a significantly higher number of distractors fixated before targets shown in an incongruent color ($M = 1.19$, $SD = 0.29$) compared with targets presented in a congruent color ($p < 0.05$) ($M = 0.94$, SD = 0.27). The other guidance indicators were not influenced by color type.

FIGURE 2: Typical examples of a dynamic map of the number of distractors fixated before the target as a function of time for two types of color



IV.1.B Effect of level of detail

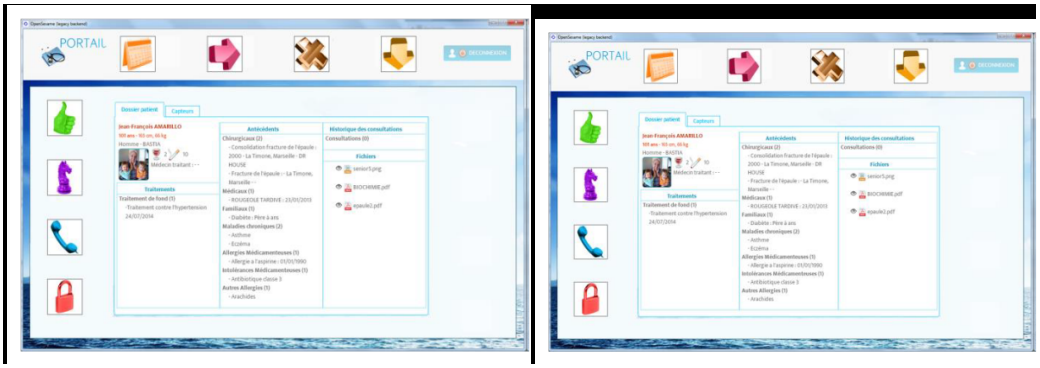
Results also showed that level of detail had no effect on mean reaction times, $F(1, 22) = 0.042$, ns). Age did not modulate this lack of effect of level of detail on reaction times, $F(2, 20) = 0.216$, *ns*. When we only considered results for targets that were strongly linked to their congruent color, we found the same results as when all the targets were considered. They therefore did not allow us to show an effect of level of detail on reaction times, $F(1, 22) = 1.662$, *ns*, regardless of age group, $F(2, 20) = 0.53$, *ns*. However, when we only considered targets that were weakly linked to their congruent color, we observed a significant effect of level of detail on reaction times, $F(1, 22) = 4.44$, $p < 0.05$. Targets with a high level of detail (photos) were located significantly faster ($M = 1846.4$ ms, $SD = 173.8$) than those with a low level of detail (drawings) ($M = 1905.3$ ms, $SD = 179.4$). Age did not modulate the effect of level of detail for these targets, $F(2, 20) = 0.142$, *ns*, as shown by the results in the following table:

TABLE 4: Reaction times of younger and older participants for targets weakly linked to their congruent color, according to level of detail

	Older		**Younger**	
	Mean reaction time (ms)	***SE***	**Mean reaction time (ms)**	***SE***
Drawing	2340.9	272.9	1472.8	153.1
Photo	2279.6	258.0	1412.5	152.2

As we also wanted to know more about the origin of the level of detail effect on reaction times for targets weakly linked to their congruent color, we analyzed the eye-tracking data for these targets. As far as our guidance indicators are concerned, results showed no effect of level of detail. For our visual search efficiency indicators, however, initial saccade latency was significantly influenced by level of detail, $F(1, 17) = 8.35$, $p < 0.01$, with a significantly greater initial saccade latency for the lower level of detail ($M = 310.4$ ms, $SD = 55.1$) than for the higher one ($M = 275.1$ ms, $SD = 45.5$).

FIGURE 3: Typical examples of a dynamic map of initial saccade latencies for the two levels of detail



IV.2 RESULTS FOR LEXICAL TARGETS

Results showed that type of color had no significant effect on reaction times, $F(2, 21) = 0.37$, *ns*, and age did not modulate this lack of effect, $F(3, 19) = 1.76$, *ns*. When we only considered results for lexical targets that were strongly linked to their congruent color, results also showed a lack of effect of type of color on reaction times, $F(2, 21) = 1.98$, *ns*, and age did not modulate this lack of effect, $F(3, 19) = 0.84$, *ns*. Results were the same when we only considered targets that were weakly linked to their congruent color, $F(2, 21) = 0.18$, *ns*, and age did not modulate this lack of effect, $F(3, 19) = 1.09$, *ns*. Analysis of eye-tracking data revealed a lack of color type effect on the guidance and visual search efficiency indicators for all lexical targets, regardless of the strength of the concept-congruent color link.

V DISCUSSION

V.1 EFFECT OF TYPE OF COLOR ON LOCATION PERFORMANCES

The results of the present study supported our second hypothesis that the congruent color-concept link influences the implementation of a type of top-down control for the location of *figurative* targets representing real objects.

First, reaction times were longer when the figurative targets were shown in an incongruent color, rather than in their congruent color or in black and white (these two conditions did not differ significantly on reaction times). This can be explained by the implementation of top-down processes. First, mean initial saccade latencies above 250 ms allowed us to conclude that our results were not due to a salience effect arising from the mere presence of colors. These relatively long latencies corresponded to *voluntary* saccades guided by endogenous factors (i.e., related to the task being performed) (see Casteau, 2012, for a review). In addition, the lengthening of reaction times was the same across both age groups, despite generally longer reaction times for young people and seniors. Moreover, the effect of type of color seemed to depend on the strength of the concept-congruent color link, as we observed it for targets with a strong link, but not a weak one. It appears to be the strength or otherwise of the congruent color-concept link, and not the mere presence of color, that caused this effect, which therefore arose from participants' previous knowledge and experience of the concept.

Furthermore, the eye-tracking data suggested that this lengthening of reaction times in the presence of incongruent colors for strongly linked targets was due to poorer

quality target guidance during the trial, as reflected in the number of distractors fixated before the target. These eye-tracking results indicate that the incongruent color-concept interference was related to a deterioration in target guidance. Moreover, our results did not support our hypothesis that type of color allows for the implementation of top-down processes in the location of *lexical* targets.

Based on TAM (Zelinsky, 2008), these results indicate that if a culturally accepted color is strongly associated with a concept, it forms part of the mental representation (or model) of that concept. This congruent color is then used to build the target map, after a comparison between the mental representation of the target and the perceived visual scene. This target map serves to guide the gaze to the target. Accordingly, when the target is associated with an incongruent color, the quality of that guidance is poorer, as it is based on the target's congruent color. However, the congruent color does not improve guidance to the target relative to black and white. This could be due to the fact that the congruent color is related not to the object but to the concept that the object represents, thus reducing the strength of the concept-congruent color link.

Results indicated that the mental representations of lexical targets do not include congruent colors. This appears to be consistent with the theory put forward by Paivio (1969), whereby the mental representations of words are symbolic and have no perceptual equivalent. It is also in line with studies (Nicholson & Humphrey, 2003; Takana & Presnell, 1999) showing that the colors of objects are stored in long-term memory and, to some extent, form part of the mental representations of these objects in memory.

V.2 EFFECT OF LEVEL OF DETAIL ON LOCATION PERFORMANCES

Results also supported our first hypothesis that the level of detail of figurative targets representing familiar, real-life objects influences the implementation of top-down control during a target location task, but only when targets were weakly linked to their congruent color.

A high level of detail improved location times when figurative targets were weakly linked to their congruent color, with a similar level of improvement for both age groups. These results led us to surmise that a kind of top-down process was taking place here, with participants using the knowledge they had about the appearance of the target (more accurate with a high level of detail). Moreover, given the heterogeneous shapes of the distractors, improved reaction times could only be due to top-down processes (Madden 2007).

The eye-tracking data showed that this improvement was due to lower initial saccade latencies when the targets had a high level of detail. Mean initial saccade latencies above 250 ms allowed us to conclude once again that these saccades were *voluntary*, guided by endogenous factors (related to the task at hand), Thus supporting the top-down origin of the observed effects.

Returning to TAM (Zelinsky 2008), we can assume that these results reflected the level of detail in the mental representations of the figurative targets. The first saccade is programmed according to the activated areas in the target map, which are those that contain stimuli most like the target's mental representation. The more similar the stimuli to the target's mental model, the more highly activated the areas corresponding

to these stimuli in the target map. Mental models contain a great deal of detail, so because photos contain more details than drawings, they resemble these mental models more closely. Photos therefore give rise to more intense activations in the target map than drawings. The first saccade should therefore be initiated faster with photos than with drawings.

V.3 INTERACTION OF COLOR AND LEVEL OF DETAIL EFFECTS

Our results revealed an effect of the interaction between type of color and level of detail on figurative target location performance, depending on the strength of the concept-congruent color link. These results can be linked to the study by Tanaka and Presnell (1999), who showed that the nature of the knowledge used to perform perceptual tasks (object recognition) varies according to the type of stimuli presented and participants' knowledge of them. These authors went one step further, suggesting that, depending on the stimuli and what people know about them, the knowledge about the visual features used to construct the mental representation of the target differs not only in terms of the nature of these visual features, but also in terms of the weight given to them in this representation.

We can therefore assume that there is a hierarchy in the use of figurative target model characteristics for target location, depending on the type of stimulus that is presented. This model does not remain static during a location task, and the choice of features used to improve location time performance may be scalable and depend on which stimuli are used and the knowledge participants have about the target. To test

this hypothesis, we could use a methodology featuring eye-tracking, similar to that developed by Towal, Mormann, and Koch (2013), who tested the validity of decisionmaking models that included the role and interaction of two factors (perceptual properties and the value of these alternatives) in the decisionmaking process.

V.4 VISUAL INFORMATION PROCESSING LEVELS AND TOP-DOWN PROCESS IMPLEMENTATION

We found that the color and level of detail of figurative targets allowed for the implementation of top-down processes during our location task. But at what visual information processing level does this implementation occur during a location task? There is a large body of evidence that many cognitive processes take place unconsciously. For example, Deplancke, Madelain, Gorea, and Coello (2013) revealed the existence of unconscious vision for motor actions, dissociated from conscious vision for perception, while Ramachandran and Gregory (1991) showed that it is possible to unconsciously detect movements that take place in areas of the visual field that are not consciously perceived because of the presence of scotoma. In addition, Scott and Dienes (2008) highlighted nonconscious implicit learning in the acquisition of new knowledge. Finally, Pelham, Carvallo, and Jones (2005) showed that humans tend to be unconsciously attracted to things that look like them.

So what about the top-down processes we highlighted, involving the color and level of detail of figurative targets? Are they implemented unconsciously or consciously during a location task? To answer this question, we will need to use the so-

called *dissociation* methods described by Schmidt and Vorberg (2006), which can separate conscious from unconscious processes.

Furthermore, Posner (1980) concluded that during a visual search task involving attentional processes, focus direction may be indirect and not be accompanied by eye movements. It might have been worthwhile checking this in our study. The ability to indirectly orient attentional focus may vary from one individual to another, depending in particular on age, and may be involved in the implementation of the top-down processes we highlighted. To verify this ability, prior to the experiment, we could have administered a stimulus detection task that required the gaze to remain motionless, using the threshold detection, evoked potential amplitude, or reaction time measures described by Posner (1980).

VI CONCLUSION: CONTRIBUTIONS AND PERSPECTIVES

To the best of our knowledge, this study was the first to make it possible to identify the impact of color and level of detail on location task performance. Based on these results, we were able to propose recommendations for the graphic features of icons and labels in the HADAGIO portal. In the experimental paradigm we used, reaction times allowed us to assess the level of difficulty for the two factors we studied, namely color type and level of detail. Our goal was not to find graphics that would directly improve older users' location reaction times, but instead to identify the graphics needed to make this task easier to accomplish. Our results indicated that icons (i.e., figurative targets) should have a high level of detail when they represent objects known to users. When

choosing colors to associate with these icons, it is important to check that they are congruent with the concepts represented by the icons, by conducting a survey like the one we implemented in this study. If the colors chosen are not congruent with the concepts represented, the icon location task will be harder to accomplish. Where there are doubts about this congruence, it is best to leave the icons in black and white, as we showed that there were no significant differences between location times when the targets were in black and white or in a congruent color, with both types of colors significantly improving location times relative to incongruent colors. For lexical targets, we found that the choice of associated color had no influence on the difficulty of the location task. These recommendations are valid for both younger and older people. An interesting avenue to pursue would be to study whether the results we achieved with eye tracking can be corroborated by subjective measures such as the pleasure felt or perceived ease of target location in different conditions. Some studies have shown that it is useful in studies like ours to combine objective eye-tracking data with subjective data (Griffey & Little, 2014; Keul, Hutzler, Frauscher, & Voigt, 2004).

Furthermore, our experimental design had the particularity of being based on the use of an eye-tracking device. This allowed us to identify the causes of changes in reaction times according to condition. Moreover, these results for eye movements enabled us to make strong assumptions about the nature and use of the visual features of a target's mental representation during the location task. We intend to test this hypothesis in a future study.

Finally, this study was a successful experiment in using a portable eye-tracking device in ecological conditions with an older audience. Although lighting conditions in the participants' homes varied, we were generally able to control them, as calibration was only unacceptably poor for 16.7% of participants (three seniors and one young person). This level of success would have been unthinkable even a few years ago. Our experiment is a good illustration of the new opportunities that are emerging thanks to technical advances in portable eye-tracking devices. It therefore complements studies using eye tracking with specific audiences such as infants (Griffey et al., 2014), and shows that it is now possible to effectively use these devices with older individuals, both in the context of ergonomic interventions intended to optimize the usability of new technology interfaces, and in the context of research in ecological conditions.

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ABSTRACT

As part of a project to design more ergonomic web-application portals for older users, we established recommendations on color choices and the level of detail needed to make it easier for seniors to locate icons and lexical labels. The experimental protocol featured an original combination of eye tracking and an ecological environment (participants' homes). Participants had to locate different targets in different color and detail conditions. Results showed that the combination of a figurative target with an incongruent color increased target location times, but only if there was a strong target

concept-congruent color link. Furthermore, a high level of detail for figurative targets improved reaction times, but only when there was a weak concept-congruent color link. These effects were linked to the implementation of top-down processes.

Keywords: Eye Tracking, Information Location Task, Older Adult, Color, Level of Detail, Top-Down Processes