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1 **Looking for a word or for its meaning? The impact of induction**
2 **tasks on adolescents' visual search for verbal material**

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Abstract (250 words)

An eye-tracking experiment was conducted to examine whether the pre-activation of different word processing pathways by means of semantic versus perceptual induction tasks could modify the way adults and 11 to 15 years-old adolescents searched for single target words within displays of nine words. The presence within the search displays of words either looking like the target word or semantically related to the target word was manipulated. The quality of participants' lexical representations was evaluated through three word identification and vocabulary tests. Performing a semantic induction task rather than a perceptual one on the target word before searching for it increased search times by 15% in all age groups, reflecting an increase in both the number and duration of gazes directed to non-target words. Moreover, performing the semantic induction task increased the impact of distractor words that were semantically-related to the target word on search efficiency. Participants' search efficiency increased with age because of a progressive increase in the quality of adolescents' lexical representations, which allowed participants to more quickly reject the distractors on which they fixated. Indeed, lexical quality scores explained 43% of the variance in search times independently of participants' age. In the simple visual search task used in this study, fostering semantic word processing through the semantic induction task slowed down visual search. However, the literature suggest that semantic induction tasks could, in contrast, help people find information more easily in more complex verbal environments where the meaning of words must be accessed to find task-relevant information.

Number of words in the main text: 9075

51 A majority of European teenagers use the Internet daily (Smahel et al., 2020), and in the
52 USA many of them report that they are "almost constantly" online (Pew Research Center,
53 2018). Popular uses include social networking, playing games, and searching for information
54 of interest. Most, if not all, of these activities involve the selective scanning of words, sentences,
55 or texts, which places a heavy burden on cognitive and language processes (Wylie et al., 2018).
56 Prior research suggests that the ability to scan verbal displays in order to find relevant
57 information for the ongoing task develops progressively during childhood and adolescence
58 (Hirsh, 2000; Kaakinen et al., 2015; Potocki et al, 2017). In this context, the examination of
59 adolescents' proficiency in visual search for single words amongst other words becomes
60 important to explain the challenges they might face when using more complex digital
61 environments. However, research on the foundational aspects of visual search for words or
62 phrases is still uncommon (for examples and reviews, see Boetcher & Wolfe, 2015; Vibert et
63 al., 2019; Zhou et al., 2017). In particular, very few studies have examined the development of
64 visual search for target words amongst other words during adolescence (Seassau & Bucci, 2013;
65 Vibert et al., 2019).

66 Data from previous studies, which investigated how children select task-relevant
67 websites from search engine result pages, indicated that young adolescents were more sensitive
68 to the visual features of words than to the meaning of the phrases that described the websites
69 (Walraven et al., 2008; Zhang & Quintana, 2012). For instance, Rouet et al. (2011) found that
70 6th graders tended to select irrelevant phrases (e.g., the highest train in the world) in response
71 to a search query (e.g., the highest mountains in the world) if the matching keywords were
72 capitalized (e.g., the HIGHEST train in the WORLD). However, when 6th graders read a short
73 text about the search topic before performing the search, they were better able to select the
74 semantically relevant menu entries (Rouet et al., 2011). Hence, fostering semantic processing

75 by asking adolescents to perform a semantic task before searching for verbal information may
76 help them more successfully find relevant information within texts or webpages.

77 The main goal of the present work was to examine whether the pre-activation of
78 different word processing pathways, by means of either a semantic or a perceptual induction
79 task that participants performed before the visual search phase, could influence the way
80 adolescents and adults scan simple verbal displays when searching for a target word. The theory
81 of attentional sensitization of unconscious cognition (Kiefer & Martens, 2010) was used as a
82 framework to compare the impact of semantic versus perceptual induction tasks on visual
83 search efficiency. This simple experiment, in which participants searched for one word within
84 a display of nine words that were distributed across the screen, was viewed as an essential step
85 towards understanding to what extent induction tasks may influence verbal information search
86 within more complex environments.

87 The data were compared with those obtained in Vibert et al.'s (2019) first experiment,
88 which assessed the influence of words that resembled the target word (orthographic distractors)
89 or were semantically related to the target word (semantic distractors) on visual search for words
90 within lists by adolescents, but did not assess the impact of induction tasks on the search
91 process. Other differences between the two studies were that in the present experiment, a
92 comparison group of adult participants was included, and the search displays were created in
93 such a way that the distance between words across the entire screen ensured that only one word
94 could be foveated at a time, which was not the case when lists were used. In addition, the quality
95 of participants' lexical representations (Perfetti & Hart, 2002; Perfetti & Stafura, 2014) was
96 evaluated through three word reading and vocabulary tests instead of only a single word
97 identification test. As in Vibert et al., the presence within the search displays of orthographic
98 or semantic distractors was manipulated.

99

100 Influence of task demands and cognitive task-set on word processing

101 Whether in search lists, social network feeds or extended texts, access to target
102 information depends on the reader's identification of words that match their search goals.
103 Cascaded, activation-type models of word recognition assume that two different processing
104 pathways may be used to identify a word: the *non-lexical* pathway, which consists in matching
105 phonemes with the graphemes represented by the letters of the word, and the *lexical* pathway,
106 which consists in directly using the semantic representations of words stored in memory to
107 recognize the word. After a first perceptual analysis of the letters that compose the word, the
108 reader may preferentially use one of the two pathways. Whereas young readers generally use
109 the non-lexical pathway, older readers retrieve the orthographic, phonological, and semantic
110 components of lexical representations synchronously and may use the two pathways
111 simultaneously (Coltheart et al., 2001).

112 As a result, when skilled readers identify a word, its semantic associates as well as
113 visually similar words may become primed in memory (Boot & Pecher, 2008; Carreiras et al.,
114 1997; Heil et al., 2004; Rodd, 2004). Even though these processes are viewed as “automatic”
115 and do not reach conscious awareness, the word processing literature suggests that the way the
116 visual form and meaning of written words are processed depends on task demands (Dampuré
117 et al., 2014; Kiefer & Martens, 2010; Reichle et al., 2012, Vibert et al., 2019), and/or on the
118 availability of attentional resources (Dampuré et al., 2019; Smith et al., 2001).

119 The task-dependency of lexical processing was formalized by Kiefer and Martens’
120 (2010) theory of the attentional sensitization of unconscious cognition. They proposed that a
121 particular word identification pathway (i.e., through the words’ orthography and phonology or
122 through the words’ meaning) can be sensitized and the other desensitized according to the
123 nature of the verbal task to come. This proactive control of the “task-set” by the cognitive
124 system would influence both conscious and unconscious processes. Kiefer and Martens

125 assumed that the semantic word processing pathway (i.e., the lexical pathway) is used
126 preferentially to access lexical representations when the meaning of words is particularly
127 relevant for a task, whereas the perceptual word processing pathway (i.e., the non-lexical
128 pathway), which accesses lexical representations based on the words' visual form (i.e., their
129 orthography and/or phonology), would be desensitized. In other words, Kiefer and Martens'
130 theory assumes that the cognitive system can foster access to lexical representations of written
131 words through either their visual form or their meaning according to the characteristics of the
132 ongoing task.

133 In addition, the attentional sensitization theory predicts an impact of currently active
134 task-sets on unconscious processing. In particular, previously performed verbal tasks should
135 differentially sensitize the perceptual and semantic word processing pathways according to
136 which of the two pathways was the most relevant. Kiefer and Martens (2010) asked participants
137 to perform an induction task, which involved either the meaning (semantic induction task) or
138 the visual form (perceptual induction task) of words, before performing a lexical decision task
139 that included subliminal semantic priming. The nature of the induction task strongly modulated
140 subliminal word processing. For hundreds of milliseconds, subliminal semantic priming was
141 larger after the semantic induction task and decreased after the perceptual induction task.
142 Setting up a semantic task-set by performing a semantic induction task fostered the semantic
143 word processing pathways in subsequent verbal tasks, whereas performing a perceptual
144 induction task fostered the use of perceptual word processing pathways (Kiefer, 2012). As a
145 plausible implication, performing either perceptual or semantic induction tasks before engaging
146 in visual search for words may impact the way adolescents and adults process words during the
147 search phase, and ultimately influence search efficiency.

148

149 **Visual search for words by adolescents and adults**

150 During visual search for words, people often have to actively scan a display to find the
151 target word (Dampuré et al., 2014; Thornton & Gilden, 2007). When a distractor word is
152 fixated, the searcher must reject it as fast as possible using foveal vision, but must also decide
153 where to look next according to what is perceived of the other words in the display. Because
154 memorizing the target word primes the target's visual and semantic features in the mental
155 lexicon, the words that have perceptual and/or semantic features in common with the
156 representation of the target word kept in memory attract the searcher's attention (Dampuré et
157 al., 2014; Vibert et al., 2019). According to models of visual search (Wolfe et al., 2011;
158 Zelinsky, 2008), the attended/fixated item must reach awareness to be classified as a distractor
159 or a target. In contrast, the features that guide the searcher's attention to particular items in the
160 peripheral visual field do not always reach conscious awareness (Huettig et al., 2011; Soto et
161 al., 2005; Van Zoest & Donk, 2010), which means that part of attention guidance within the
162 display results from automatic, unconscious processes.

163 Only a few studies have used eye movement recordings to assess the impact of
164 orthographic and semantic distractor words on visual search for target words within lists (Léger
165 et al., 2012; Vibert et al., 2019) or displays in which words are distributed across the screen
166 (Dampuré et al., 2014; Zhou et al., 2017). The number of gazes directed towards each distractor
167 word during the search process was taken as evidence of their ability to attract people's attention
168 when perceived in the peripheral visual field, while gaze durations informed the amount of
169 processing needed to reject the words at which the person gazed (Zelinsky, 2008).

170 Eye-tracking evidence corroborates the influence of words' features on people's visual
171 exploration of verbal displays. When orthographic distractors were present, adults' and
172 adolescents' search times strongly increased (Dampuré et al., 2014; Vibert et al., 2019), because
173 orthographic distractors were gazed at more often and for longer durations than other words.
174 Interestingly, semantic distractors were also gazed a larger number of times than target-

175 unrelated words (Dampuré et al., 2014; Vibert et al., 2019), probably because they became
176 activated when participants learned the target word. In contrast, they were not gazed at for
177 longer durations than other words, because they did not resemble the target word and were thus
178 easily rejected. Vibert et al. (2019) also examined the effect of ageing on adolescents' visual
179 search for words. Participants' search times decreased between the ages of 11 and 15, because
180 older adolescents directed fewer gazes to distractor words and also gazed at them for shorter
181 durations.

182

183 **The role of lexical quality in adolescents' visual search for words**

184 Learning to decode written words plays a central role in children's reading development
185 (Perfetti, 1992; Plaut & Booth, 2000; Stanovich, 1980). The progressive automation of word
186 decoding up until the age of 12 may free mental resources for processing the words seen in the
187 parafoveal/peripheral visual field during visual search for verbal information. The lexical
188 quality hypothesis (Perfetti & Hart, 2002) assumes that mental representations of words include
189 three main components, i.e., their orthographic, phonological, and semantic features. Another
190 component refers to the strength of the connections between these features (Perfetti, 2007;
191 Verhoeven et al., 2011; Verhoeven & Perfetti, 2011). High-quality lexical representations are
192 based on well-specified orthographic, phonological, and semantic components that are strongly
193 connected to one another. According to the lexical quality hypothesis, less skilled readers do
194 not retrieve all components of lexical representations synchronously during word recognition
195 (Nation, 2009; Perfetti & Hart, 2002). However, as children get older, they progressively
196 acquire higher quality lexical representations that facilitate a flexible use of the different
197 features of words to access lexical representations (Perfetti, 2007; Verhoeven & Perfetti, 2011).

198 Prior research suggests that the better quality of older adolescents' lexical
199 representations facilitates the use of both the perceptual and semantic features of words for top-

200 down guidance during visual search for words (Vibert et al., 2019). In particular, older
201 adolescents were better able to reject words without gazing at them directly. Therefore, young
202 adolescents' difficulties in searching lists of verbal information, as one could access via search
203 engine results pages, may result from insufficiently developed word decoding abilities and
204 lexical representations.

205

206 **The current experiment**

207 The main goal of this study was to find out whether performing either a perceptual or
208 semantic induction tasks before searching for a target word impacted the moment-by-moment
209 ways that adolescents and adults processed words during the search phase. According to Kiefer
210 and Martens' (2010) theory, performing induction tasks before the search may impact both the
211 processes involved in the rejection of distractor words and the "automatic" attention guidance
212 processes that determine the order in which words are gazed within the search display.

213 Fifth, seventh, and ninth graders - as well as adults - were provided with a target word,
214 with which they had to perform either a perceptual or a semantic induction task. Each target
215 word was an example of a category (e.g., "bird" for the target word "raven"). In the perceptual
216 task, participants had to say whether the target word contained the letter "o", and then to spell
217 it aloud. In the semantic task, participants were asked to give two other examples of the target
218 word's category (i.e., two other birds' names in the present case). Then, participants were tasked
219 to search for the target word amongst eight other words, which could include orthographic or
220 semantic distractors. Participants' search times were assessed as a function of age group,
221 induction task, and the type of distractors included in the search display. Participants' eye
222 movements were recorded during the search phase, and were analyzed by assessing the number
223 and average duration of gazes directed towards non-target words before the participant clicked
224 on the target word. Because displaying the words in vertical lists constrained the search strategy

225 and limited the impact of word features on attention guidance (Léger et al., 2012; Ojanpää et
226 al., 2002), word displays in which only one word could be foveated at a time were used
227 (Dampuré et al., 2014). In addition, participants had to perform a word identification test, a
228 vocabulary test and a category fluency test, which were combined to obtain a composite score
229 that was used as an estimate of lexical quality.

230 Performing a semantic rather than a perceptual induction task on the target word should
231 foster access to the lexical representations of words through their meanings, rather than through
232 their visual form, during the search process. According to the feature-integration theory of
233 visual search (Treisman & Gelade, 1980, see also Wolfe, 2020), **the simplest visual features of**
234 **the letters that make up the words**, in particular their first and last letters, may be first quickly
235 processed in parallel across the whole search **display. Then, the binding** of these simple features
236 into recognizable and meaningful words **would require** a serial deployment of attention across
237 the display. When the target word is known in advance, using the perceptual word processing
238 pathway when scanning the display should facilitate quick rejection of non-target words, which,
239 for instance, can be rejected as **soon as the features of their first or last letter** differs from **those**
240 **of the target word's first or last letter**. In contrast, fostering the semantic word processing
241 pathway should slow down the search process, because accessing the meaning of non-target
242 words takes more time and, in most cases (except maybe for orthographic distractors), is not
243 necessary to reject them.

244 Hence, the first hypothesis (H1) was that the perceptual induction task should decrease
245 the duration of gazes directed to non-target words and accelerate the search process compared
246 to the semantic task. Conversely, performing the semantic task rather than the perceptual task
247 may increase the number of gazes directed to non-target words by prompting participants to get
248 the meaning of each word. The second hypothesis (H2) was that performing the semantic task
249 should promote the activation of the semantic associates of the target word, while reducing the

250 activation of orthographically-similar words. As a result, the semantic task should induce a
251 particularly strong increase in the number and/or average duration of gazes directed to non-
252 target words compared to the perceptual task when semantic distractors are present in the
253 display. A third hypothesis (H3) was that the time needed to find target words should decrease
254 with age, because of a decrease in both the number and the average duration of gazes directed
255 to non-target words. The fourth hypothesis (H4) was that progress in visual search efficiency
256 should be associated with an increase in the quality of participants' lexical representations. As
257 such, the participants displaying higher lexical quality scores should find the target words faster
258 because of a decrease in both the number and duration of gazes directed to non-target words.

259 Beyond these formal hypotheses, eye movement data were used as an exploratory tool
260 to get more information about the cognitive mechanisms underlying the impact of induction
261 tasks for each age group.

262

263

Material and Methods

264 Participants

265 All participants were native French speakers and had normal or corrected-to-normal
266 vision. They included 24 fifth graders (M age=10.9 years, SD =.3, 9 females), 24 seventh graders
267 (M =12.5 years, SD =.4, 13 females), 30 ninth graders (M =14.8 years, SD =.4, 16 females), and
268 24 young adults (M =27.5 years, SD =3.8, 12 females). For adolescent participants, the
269 experiment was conducted in five different schools in a medium-sized French town. Permission
270 was sought from the school, the teacher, and from all students' parents or legal guardians by
271 sending a parental consent form. After written and informed permission was obtained, all
272 students were read a verbal script and were asked to assent to their participation in the study.
273 The 24 adult participants were volunteers who provided their written informed consent before
274 the study. They were recruited from the general population by word of mouth. They were

275 selected according to both their gender and level of education in order to get a representative
276 sample of the various levels of education reached by average populations of French female and
277 male ninth graders according to the French National Institute for Statistics and Economic
278 Studies (INSEE).¹ As such, the sample included three women and three men **who quit school**
279 after ten or eleven years of education and did not get a high school degree, four men and three
280 women who stopped studying after completing high school degree (after twelve years of
281 education in France), three men and four women who went to university for one to three years
282 and had therefore 13 to 15 years of education, and two men and two women who had Master's
283 degrees and had therefore 17 years of education.

284

285 **Apparatus**

286 Participants' eye movements were recorded using a TOBII 1750 eye tracker as in Vibert
287 et al. (2019). The eye tracker provided gaze positions at a sampling frequency of 50 Hz. The
288 distance between participants' eyes and the eye-tracker was adjusted to get the best eye
289 detection and eye movement recordings as possible for each participant. Depending on the
290 participants, the optimal viewing distance varied between 477 and 817 mm. As a result, 10 mm
291 on the screen of the eye-tracker covered .70 to 1.20 degrees of visual angle depending on
292 participants. Léger et al. (2012) estimated the effective precision of this eye-tracker at
293 $M=.54$ deg of visual angle ($SD=.30$), which in this experiment corresponded to 4.5 to 7.7 mm
294 on the screen depending on the viewing distance.

295

296 **Visual Search Material**

¹ At the time the experiment was conducted, full review and approval of the study by an ethics committee or an Institutional Review Board was not required according to institutional and national guidelines and regulations. The experiment was conducted according to the ethical guidelines of the Declaration of Helsinki.

297 The visual search material was composed of 96 sets of nine French common nouns. The
298 nine words included a target word and eight other words and were displayed together in black
299 against a white background. All words were written in lower case letters in Arial font. In order
300 to ensure some homogeneity in the verbal material, all 624 words used in the sets of words had
301 4 to 11 letters and 2 or 3 syllables. Most of them (620 out of 624, 99.4%) had a lexical frequency
302 greater than two per million in corpora of third- to fifth-grade readers used in French elementary
303 schools, according to the Manulex (Lété et al., 2004) and/or Novlex (Lambert & Chesnet, 2001)
304 databases. The lexical frequency of the four last words varied between 1.0 and 1.5 per million,
305 because it was sometimes difficult to find sufficient numbers of semantic or orthographic
306 distractors that fitted with the minimum lexical frequency criterion.

307

308

(TABLE 1 ABOUT HERE)

309

310 *Creation of word sets.* The 96 word sets included 72 experimental sets and 24 filler sets.
311 The 72 experimental sets were built around 24 target words (i.e., three sets per target word) as
312 in Vibert et al. (2019). Each target word was an exemplar from a category (see Vibert et al.,
313 2019 for details), which was used in the semantic induction task to prompt participants to
314 produce their own exemplars of the category (Table 1). For instance, “corbeau” (raven) was an
315 exemplar of “oiseau” (the bird category). Three different nine-word sets were built around each
316 of the 24 target words as follows (Table 2):

317 - The “orthographic set” included the target word, four orthographic distractors that
318 shared at least the first and last two letters with the target word, and four filler words
319 that were unrelated to the target word.

320 - The “semantic set” included the target word, four semantic distractors that were
321 semantically related to the target word (Léger et al., 2012), and the same four filler
322 words as in the orthographic display.

323 - The “neutral set” included the same four filler words as in the previous sets and four
324 additional neutral distractor words that were also unrelated to the target word.

325 The 408 words used in the experimental sets of words had $M=7.00$ letters ($SD=1.31$)
326 and $M=2.26$ syllables ($SD=0.45$). There was no significant statistical difference in lexical
327 frequency (Kruskal-Wallis ANOVA, $H(4, N=408)=8.30, p=.08$) between the target words
328 ($M=25.2$ per million, $SD=20.6, Mdn=21.6$), the filler words ($M=22.0, SD=24.4, Mdn=11.3$), the
329 neutral distractor words ($M=29.5, SD=38.3, Mdn=13.3$), the semantic distractor words
330 ($M=40.1, SD=63.9, Mdn=21.9$) and the orthographic distractor words ($M=21.1, SD=29.8,$
331 $Mdn=9.7$) across the 24 target words. There was also no significant difference in the number of
332 letters (Kruskal-Wallis ANOVA, $H(4, N=408)=3.38, p=.50$), number of syllables
333 ($H(4, N=408)=7.79, p=.10$) and number of orthographic neighbors ($H(4, N=408)=7.24, p=.12$)
334 between the target words, the filler words and the three types of distractor words.

335

336 (TABLE 2 ABOUT HERE)

337

338 *Construction of search displays.* In the search displays, the nine words of each set were
339 arranged to maximize the distance between the words while avoiding horizontal or vertical
340 alignments. A unique nine-word arrangement was built for each target word within a six-line
341 by five-column grid. The grid was divided into five areas, i.e., a central cross-like area and four
342 peripheral, corner-like areas (Figure 1A). The nine words were randomly assigned to nine cells
343 in the grid, under the condition that there had to be a minimum of one word in each of the five
344 areas. The target word had to be located in one of the four peripheral areas in order to maximize

345 the impact of the distractor words. Of course, the grid that was used to build the display was
346 invisible to participants (panels B and C of Figure 1).

347

348 (FIGURE 1 ABOUT HERE)

349

350 The resulting nine-word arrangement was used to generate the three experimental
351 displays in which this target word was searched. Importantly, the positions of the target word
352 and the four filler words were held constant across the three displays. The positions of the four
353 set-specific distractor words were also the same in the three sets, but their nature (orthographic,
354 semantic, or neutral) changed according to set type (Table 2 and Figure 1).

355 In the 72 experimental word displays, the four neutral, orthographic, or semantic
356 distractors were written in large 24-point Arial font (9 mm in height on the eye-tracker screen),
357 whereas the target word and filler words were written in smaller 14-point font (5.5 mm in
358 height) in order to maximize the impact of distractor words (Figure 1). The distance between
359 the center of each word and that of its closest neighbor was at least 35 mm, i.e., much higher
360 than the effective precision of the eye tracker (see above). Since the human fovea covers 2.0°
361 of visual angle, i.e. 16.6–28.6 mm on the screen depending on the distance from it at which
362 they sat, the participants could only foveate one word at a time.

363 Twenty-four filler displays, which were different from the experimental displays, were
364 used in this experiment. In these displays, which were not considered in data analyses, most of
365 the target words (16 out of 24) were placed within the cross-like central area. The filler trials
366 were interspersed between the experimental trials to prevent participants from immediately
367 searching for the target word in the peripheral areas. As in the experimental displays, the set-
368 specific distractor words were written in large font, whereas the filler words were written in
369 smaller font. In 16 of the filler displays, however, the target word was written, as the distractor

370 words, in large font, to prevent participants from immediately searching for the target word
371 within the words written in smaller font.

372

373 **Lexical quality tests**

374 The quality of participants' lexical representations was evaluated by combining a
375 measure of their word identification speed, a verbal fluency test, and a vocabulary test. As the
376 three scores were all correlated with each other (all $r_s > .54$, all $p_s < .001$), z -scores for each
377 separate test were aggregated into one score per individual (see below).

378 *Word identification speed.* Participants' word identification speed was measured using
379 the "Pipe and Rat" test (Lefavrais, 1968). Participants silently read words displayed on
380 successive lines with articles (beginning with "the pipe – the rat –..."). They had to read as many
381 words as possible within 3 minutes. Half of the words were animal names and participants were
382 asked to underline all of them while reading. The number of correctly identified animal names
383 minus the number of incorrectly underlined names was an index of word identification speed.

384 *Category fluency task.* The speed of participants' access to their mental lexicon was
385 measured using a category fluency task, in which participants were given one minute to produce
386 as many different words as possible belonging to a particular semantic category, here the
387 "animals" category. The participants' score was the number of words produced in one minute.

388 *Vocabulary test.* Participants' vocabulary knowledge was assessed using a French
389 adaptation of the Mill Hill vocabulary test (Deltour, 1993). Only the second part of the test, in
390 which participants must recognize the meanings of successive words by choosing the correct
391 synonym for each word from among six options, was used in the present study, in a children-
392 adapted version that included 33 items of increasing difficulty. The score was the number of
393 words for which the correct synonym was chosen.

394

395 Design and procedure

396 For the visual search task, participants were tested individually in a single session that
397 included two blocks of 24 trials each. Participants searched for target words after performing
398 the perceptual induction task in one block, and after performing the semantic task in the other
399 block. Half of the participants began with the perceptual task, whereas the other half began with
400 the semantic task. In each block, participants were presented with three practice trials, followed
401 by 12 experimental and 12 filler trials in random order. The assignment of the 24 target words
402 between the two induction tasks and the three different types of display was counterbalanced
403 so that the type of display and induction task factors were crossed with six sets of four target
404 words and groups of six participants. As a result, each participant searched once for each of the
405 24 experimental target words in an orthographic, semantic, or neutral display, following either
406 the perceptual or the semantic induction task (four trials per condition).

407 Each trial began with a slide showing a central fixation cross, on which the participant
408 had to position the mouse cursor. When the experimenter pressed a key, the target word (e.g.,
409 raven) appeared at the center of the screen. When participants had to perform the perceptual
410 induction task, the experimenter read the word aloud, and asked the participant first to say
411 whether the word contained the letter “o”, and second to spell aloud the word letter by letter.
412 For the semantic induction task, the experimenter told participants that the target word was an
413 example of a particular category and asked them to give two other examples of this category.
414 Then, a screen showing the display in which the participant was to locate the target word
415 appeared. Participants were instructed to find the target word as quickly as possible, but without
416 making mistakes. They were also instructed not to move the mouse cursor before having located
417 the target word, but then to click on it as soon as they had found it. The response time was the
418 time that elapsed between the appearance of the word display and the participant’s click on the
419 target word.

420 To control for individual differences in mouse control ability, each participant
421 performed a speeded mouse-pointing task once before beginning the visual search experiment,
422 and once at the end of the experimental session. The task included five trials in which the
423 participant had first to position the mouse cursor on a central fixation cross. Then, a word-size
424 horizontal rectangle, which was located at a location where target words could be displayed in
425 the experimental trials, appeared on the screen. The participant had to move the mouse and
426 click within the rectangle as quickly as possible. The location of the rectangle was different on
427 each trial. The “motor reaction time” was computed as the time that elapsed between the
428 appearance of the rectangle and the moment the participant clicked in it.

429 After the visual search task, seventh graders, ninth graders and adults performed
430 individually the word identification test, the verbal fluency task and the vocabulary test, in that
431 order. Fifth graders performed individually only the verbal fluency task and the vocabulary test.
432 Indeed, the word identification test was administered simultaneously to the whole class group.
433

434 **Eye Movement Recordings**

435 The ClearView 2.7.1 software was used to record eye movements and to time slide
436 presentations and mouse clicks. Eye fixations were defined as any period where gaze stopped
437 for 60 ms or more within a 10 mm (about 1.0 degree of visual angle) diameter area. During the
438 search, a fixation was assigned to a word when it was located within 20 mm of the word, i.e.
439 the distance covered by the participant’s fovea. Fixations that were not located within 20 mm
440 of any word were removed from the analysis. Successive fixations on the same word were
441 collapsed together as one “gaze” at this word.

442

443 **Data Analyses**

444 *Visual search data.* The median “motor reaction time” obtained by each participant on
445 the two mouse-pointing tasks was subtracted from their raw response time to isolate
446 participants’ “search time”. Participants’ performance was assessed using error rate and search
447 times as dependent variables. All trials where errors were made were excluded from further
448 analyses. Search times and eye movement data were analyzed using linear mixed models that
449 were obtained using the JASP software (version 0.16.0.0). Each model included participants
450 and items as random intercepts, and as many as possible by-participant and by-item random
451 slopes. Satterthwaite approximation for degrees of freedom were used to obtain **the F values,**
452 **probabilities and effect sizes. All follow-up pairwise comparisons were performed based on**
453 **adjusted least squares means, using t -tests and dummy contrast coding, with the two levels to**
454 **be compared set to -1 and 1, respectively.**

455 A logarithmic transformation was applied to search times, which were then analyzed
456 using age group, induction task (perceptual or semantic), and type of display (neutral, semantic,
457 or orthographic) and their interactions as fixed factors, and participants and items as random
458 intercepts. Participants’ eye movements were analyzed using the number and average duration
459 of gazes directed to non-target words before the participant clicked on the target word. Analyses
460 of eye movements were conducted using age group, induction task, type of display, and type of
461 word (filler words or distractor words) and their interactions as fixed factors, and participants
462 and items as random intercepts.

463

464 *Evaluation of the quality of participants’ lexical representations.* To obtain a single
465 “lexical quality” score combining the scores obtained on the three tests by each participant, a
466 composite variable was created by standardizing each score over the whole population of
467 participants, and then summing the three z -scores obtained for each participant. Because lexical
468 quality scores depended strongly on participants’ age (see below), multivariate linear regression

469 models were designed to check whether participants' quality of lexical representations and/or
470 age could predict search times and eye movement data.

471

472

473

Results

474 Visual search task

475 *Error rates.* The error rate was very low for all age groups, since participants made only
476 17 target selection errors over the 2,448 experimental trials (.7% error rate). The error rate was
477 .2% in ninth graders, .3% in adults, 1.8% in seventh graders and 2.1% in fifth graders.

478

479 (TABLE 3 AND FIGURE 2 ABOUT HERE)

480

481 *Search times.* The model for search times (Table 3 and Figure 2) revealed main effects
482 for induction task ($F(1,21)=26.40, p<.001, \eta_p^2=.56$), age group ($F(3,97)=29.82, p<.001,$
483 $\eta_p^2=.48$), and type of display ($F(2,31)=15.27, p<.001, \eta_p^2=.50$), with no significant interaction.
484 As hypothesized (H1, Table 3 and Figure 2), performing the semantic task increased
485 participants' search times (by 15.5%) compared to the perceptual task. Also, as expected (H3,
486 Table 3 and Figure 2), the speed of visual search for words increased with age since fifth
487 graders' search times were longer than ninth graders' ($t(97)=7.34, p<.001, d=1.49$) and adults'
488 ($t(97)=7.29, p<.001, d=1.48$), and seventh graders' search times were longer than ninth graders'
489 ($t(97)=5.91, p<.001, d=1.20$) and adults' ($t(97)=5.93, p<.001, d=1.20$). As in Vibert et al.
490 (2019), the presence of orthographic distractors reduced search efficiency compared to
491 instances where they were not present (Table 3 and Figure 2). Indeed, search times were longer
492 for orthographic displays than for neutral ($t(67)=5.49, p<.001, d=1.34$) and semantic displays

493 ($t(24)=3.60, p<.01, d=1.47$). Contrary to expectations, however, participants' search times were
494 not significantly different between semantic and neutral displays ($t(435)=1.09, p=.28$).

495

496 (FIGURE 3 ABOUT HERE)

497

498 *Eye movement data: number of gazes directed to non-target words.* Participants gazed
499 at about half of the non-target words and stopped searching as soon as the target word was
500 fixated. The model for the number of gazes (Figure 3) showed main effects for induction task
501 ($F(1,34)=14.84, p<.001, \eta_p^2=.30$), age group ($F(3,94)=3.19, p<.05, \eta_p^2=.09$), type of display
502 ($F(2,34)=7.00, p<.01, \eta_p^2=.29$), and type of word ($F(1, 24)=8.10, p<.01, \eta_p^2=.25$). There was
503 an interaction between type of display and type of word ($F(2,4327)=16.59, p<.001, \eta_p^2=.008$),
504 and a three-way interaction between age group, induction task, and type of display
505 ($F(6,4339)=2.47, p<.05, \eta_p^2=.003$).

506 As hypothesized (H1, Figure 3), performing the semantic task rather than the perceptual
507 one increased the average number of gazes directed to non-target words (by 13%, 4.72 ± 1.09
508 gazes versus $4.18\pm .82$). The main effect of grade revealed that, as expected (H3, Figure 3), part
509 of the increase in search speed with age was due to a decrease in the number of gazes directed
510 to non-target words (Figure 3), because fifth graders directed more gazes to non-target words
511 ($4.74\pm .93$) than ninth graders ($4.19\pm .47, t(94)=2.91, p<.01, d=.60$) and adults ($4.37\pm .65,$
512 $t(94)=1.96, p=.05, d=.40$), and seventh graders directed marginally more gazes to non-target
513 words ($4.56\pm .88$) than ninth graders' ($t(94)=1.94, p=.055, d=.40$).

514 The type of display by type of word interaction demonstrated that, as in Vibert et al.
515 (2019), the increase in search times caused by orthographic distractors was due in part to an
516 increase in the number of gazes directed to these distractors (Figure 3). Indeed, participants
517 directed more gazes to orthographic distractors ($2.82\pm .82$) than to neutral distractors ($2.11\pm .62,$

518 $t(340)=5.53, p<.001, d=.60$), whereas the numbers of gazes directed to semantic ($2.18\pm.63$) and
519 neutral distractors did not differ significantly ($t(340)=.58, p=.56$). In addition, participants
520 gazed more often at orthographic distractors than at filler words ($2.21\pm.60$ gazes) in
521 orthographic displays ($t(340)=5.64, p<.001, d=.61$), whereas the filler words did not attract
522 significantly different numbers of gazes in orthographic ($t(340)=.96, p=.34$) or semantic
523 displays ($2.08\pm.56, t(340)=-.08, p=.94$) compared to neutral displays ($2.07\pm.73$).

524 The three-way interaction revealed in addition that the impact of induction tasks on the
525 number of gazes directed to non-target words varied according to both age group and type of
526 display (Figure 3). In fifth graders and seventh graders, the semantic task induced a greater
527 number of gazes directed to non-target words compared to the perceptual task for neutral
528 displays (fifth graders: $t(4,330)=3.59, p<.001, d=.11$, seventh graders: $t(4,330)=2.27, p<.05,$
529 $d=.07$), but not for semantic (fifth graders: $t(4,330)=1.63, p=.10$, seventh graders: $t(4,330)=-$
530 $.03, p=.98$) or orthographic displays (fifth graders: $t(4,330)=1.20, p=.23$, seventh graders:
531 $t(4,330)=1.54, p=.12$). In contrast, ninth graders and adults directed more or marginally more
532 gazes to non-target words after the semantic task than after the perceptual task for both
533 orthographic (ninth graders: $t(4,330)=2.75, p<.01, d=.08$, adults: $t(4,330)=2.22, p<.05, d=.07$)
534 and semantic displays (ninth graders: $t(4,330)=1.74, p=.082, d=.05$, adults: $t(4,330)=2.02,$
535 $p<.05, d=.06$), but not for neutral displays (ninth graders: $t(4,330)=.39, p=.70$, adults:
536 $t(4,330)=.06, p=.95$).

537

538

(FIGURE 4 ABOUT HERE)

539

540 *Eye Movement Data: Average gaze durations.* The model for average gaze durations
541 (Figure 4) revealed main effects for induction task ($F(1,82)=14.34, p<.001, \eta_p^2=.15$), age group
542 ($F(3,97)=10.82, p<.001, \eta_p^2=.25$), and type of display ($F(2,37)=17.01, p<.001, \eta_p^2=.48$). They

543 were qualified by interactions between type of display and type of word ($F(2,3792)=46.00$,
544 $p<.001$, $\eta_p^2=.02$), induction task and type of display ($F(2,1935)=3.91$, $p<.05$, $\eta_p^2=.004$),
545 induction task and age group ($F(3,106)=3.16$, $p<.05$, $\eta_p^2=.08$), and by a three-way interaction
546 between induction task, age group, and type of word ($F(3,3784)=2.80$, $p<.05$, $\eta_p^2=.002$).

547 As hypothesized (H1, Figure 4), performing the semantic task rather than the perceptual
548 one induced a weak, but significant increase in participants' average gaze durations on non-
549 target words (by 4.5%, 193 ± 38 ms versus 185 ± 38 ms). Also, as expected (H3), the main effect
550 of grade revealed that the increase in search speed with age was due in part to a decrease in the
551 duration of gazes directed to non-target words (Figure 4). Indeed, fifth graders' average gaze
552 durations (216 ± 48 ms) were longer than ninth graders' (177 ± 22 ms, $t(97)=3.87$, $p<.001$, $d=.79$)
553 and adults' (164 ± 29 ms, $t(97)=5.19$, $p<.001$, $d=1.05$). Similarly, seventh graders' gaze
554 durations (195 ± 34 ms) were longer than ninth graders' ($t(97)=2.35$, $p<.05$, $d=.48$) and adults'
555 ($t(97)=3.75$, $p<.001$, $d=.76$).

556 The type of display by type of word interaction confirmed that, as in Vibert et al. (2019),
557 the increase in search times caused by orthographic distractors resulted in part from the longer
558 duration of the gazes directed to these distractors (Figure 4). Indeed, participants gazed longer
559 at orthographic distractors (216 ± 54 ms) than at neutral distractors (175 ± 47 ms, $t(3,800)=9.09$,
560 $p<.001$, $d=.29$), whereas gaze durations on semantic (175 ± 37 ms) and neutral distractors did
561 not differ significantly ($t(3,800)=.14$, $p=.89$). In addition, participants gazed longer at
562 orthographic distractors than at filler words (190 ± 37 ms) in orthographic displays
563 ($t(3,800)=5.80$, $p<.001$, $d=.19$). Participants displayed similar gaze durations on filler words in
564 orthographic ($t(3,800)=.95$, $p=.34$) and semantic displays (191 ± 38 ms, $t(3,800)=1.30$, $p=.19$)
565 compared to neutral displays (185 ± 39 ms).

566 The induction task by type of display interaction revealed that, in accordance with
567 hypothesis 2, the semantic task significantly increased participants' gaze durations compared

568 to the perceptual task for semantic displays only (190 ± 45 ms versus 174 ± 36 ms, $t(1,935)=4.57$,
569 $p<.001$, $d=.21$), i.e., only when semantic distractors were present in the display. In contrast, the
570 increase was not significant for neutral (181 ± 41 ms versus 177 ± 43 ms, $t(1,935)=1.09$, $p=.28$)
571 or orthographic displays (204 ± 47 ms versus 202 ± 48 ms, $t(1,935)=1.79$, $p=.074$).

572 Finally, the three-way interaction revealed that regardless of the type of display, the
573 impact of induction task on participants' gaze durations on non-target words varied according
574 to both age group and type of word. In fifth graders, compared to the perceptual task, the
575 semantic task did not significantly increase participants' gaze durations on either distractor
576 words, whatever their type ($t(3,780)=1.06$, $p=.29$), or filler words ($t(3,780)=-1.56$, $p=.12$). In
577 seventh and ninth graders, the semantic task did not significantly increase participants' gaze
578 durations on distractor words (seventh graders: $t(3,780)=1.47$, $p=.14$, ninth graders:
579 $t(3,780)=.55$, $p=.58$), but had an impact on participants' gaze durations on filler words (seventh
580 graders: 205 ± 35 ms versus 185 ± 41 ms, $t(3,780)=3.70$, $p<.001$, $d=.12$, ninth graders: 186 ± 31
581 ms versus 173 ± 27 ms, $t(3,780)=1.78$, $p=.075$, $d=.06$). In adults, the semantic task increased
582 participants' gaze durations on both distractor words (167 ± 36 ms versus 157 ± 30 ms,
583 $t(3,780)=2.08$, $p<.05$, $d=.07$) and filler words (173 ± 34 ms versus 158 ± 23 ms, $t(3,780)=2.89$,
584 $p<.01$, $d=.09$).

585

586 **Lexical quality tests**

587 Lexical quality scores (Table 4) revealed a main effect of age group ($F(3,98)=25.38$,
588 $p<.001$, $\eta_p^2=.44$). Although lexical quality was not significantly different between fifth and
589 seventh graders ($t(98)=.40$, $p=.69$), it was higher for ninth graders than for seventh graders
590 ($t(98)=3.66$, $p<.001$, $d=.74$), and higher for adults than for ninth graders ($t(98)=3.95$, $p<.001$,
591 $d=.80$). Altogether, there was a strong positive correlation between participants' lexical quality
592 scores and age ($r=.62$, $p<.001$) across the whole sample of participants. According to published

593 norms for the word identification test (Lefavrais, 1968), the current sample of fifth graders
594 performed well over the grade-level norm (Table 4), which may explain why no significant
595 difference in lexical quality was found between fifth and seventh graders.

596

597 (TABLE 4 ABOUT HERE)

598

599 Because of the strong positive correlation between participants' lexical quality scores
600 and age, a multivariate regression model was designed to assess the respective impacts of
601 lexical quality and age on participants' search times. The model was significant ($F(2,98)=39.58$,
602 $p<.001$, $\eta_p^2=.45$) and revealed that, as hypothesized (H4), the participants displaying higher
603 lexical quality scores found the target words faster ($\beta=-.56$, $SE=.10$, $p<.001$). The lexical quality
604 scores explained 43% of the variance in search times independently of participants' age. The
605 models obtained for eye movement data were both significant ($F(2,98)=3.62$, $p<.05$, $\eta_p^2=.07$
606 for the number of gazes directed to non-target words, and $F(2,98)=18.58$, $p<.001$, $\eta_p^2=.27$ for
607 gaze durations). The participants displaying higher lexical quality scores directed less gazes to
608 non-target words ($\beta=-.25$, $SE=.10$, $p<.05$) and gazed at them for shorter durations ($\beta=-.50$,
609 $SE=.09$, $p<.001$). However, lexical quality scores explained only 6% of the variance in the
610 number of gazes directed to non-target words, versus 24% of the variance in gaze durations.
611 Hence, the decrease in participants' search times associated with higher lexical quality was
612 mainly caused by a decrease in gaze durations on non-target words.

613

614 **Overall data summary**

615 As hypothesized (H1), performing the semantic task increased participants' search times
616 compared to the perceptual task. This increase was due mainly to an increase in the number of
617 gazes directed to non-target words, but also to a slight increase in their average duration. In

618 addition, the speed of visual search for words increased with age (H3) because both the number
619 and duration of gazes directed to non-target words decreased, and the presence of orthographic
620 distractors reduced search efficiency compared to instances where they were not present.

621 In addition, eye movement data revealed that the impact of the semantic task on the
622 number of gazes directed to non-target words was stronger for neutral displays than for
623 orthographic or semantic displays in fifth and seventh graders, whereas the reverse was true for
624 ninth graders and adults. Regarding the duration of gazes directed to non-target words, the
625 induction task by type of display interaction showed that (H2) the semantic task had a
626 significant impact on gaze durations only when semantic distractors were present, i.e., for
627 semantic displays, but not for neutral or orthographic displays. The three-way interaction
628 between induction task, age group, and type of word demonstrated that the impact of the
629 semantic task on the duration of gazes directed to non-target words progressively extended from
630 filler words to distractor words with age.

631 Finally, participants displaying higher lexical quality scores found the target words
632 faster (H4), because they directed less gazes to non-target words and gazed at them for shorter
633 durations. Participants' lexical quality scores explained 43% of the variance in search times,
634 but only 6% of the variance in the number of gazes directed to non-target words versus 24% of
635 the variance in gaze durations. Since performing the semantic task rather than the perceptual
636 one increased the number of gazes directed to non-target words by 13%, but the average
637 duration of these gazes only by 4.5%, induction tasks had a stronger impact than lexical quality
638 scores on the number of gazes directed to non-target words, whereas lexical quality scores had
639 a much stronger impact than induction tasks on the average duration of these gazes.

640

641

Discussion

642

643 Impact of induction tasks on visual search for words

644 The experiment examined the impact of a semantic versus a perceptual induction task
645 on the search for target words within simple displays. As hypothesized (H1), irrespective of the
646 age of participants, performing the semantic induction task increased the time needed to find
647 the target word relative to the perceptual one because of an increase in both the number and
648 average duration of gazes directed to non-target words. In accordance with Kiefer and Martens'
649 (2010) attentional sensitization theory, performing induction tasks before the search impacted
650 both the processes involved in the rejection of distractor words and the “automatic” attention
651 guidance processes that determine which words are gazed at in the search display. The large
652 extent and the strength of the differential impact of semantic versus perceptual induction tasks
653 on such a simple visual search task supports the idea that semantic induction tasks may also
654 have an impact in more complex verbal environments.

655 In accordance with H3, performing induction tasks on the target words did not
656 substantially modify the development of search efficiency with age, which was similar to that
657 reported in previous studies (Léger et al., 2012; Dampuré et al., 2014; Vibert et al., 2019). As
658 in Vibert et al., participants' search times decreased from fifth to ninth grade because older
659 students fixated non-target words for less time, but also because they directed fewer gazes to
660 non-target words. Interestingly, the efficiency of visual search for words showed no further
661 increase between ninth grade and adulthood when adult participants were recruited from the
662 general population as in this study.

663 The impact of orthographic distractors was similar to what was obtained in previous
664 studies (Léger et al., 2012; Dampuré et al., 2014; Vibert et al., 2019). The presence of
665 orthographic distractors increased search times both because they attracted more gazes than the
666 other types of words and because they had to be gazed at for longer durations before being
667 rejected. Semantic distractors, in contrast, did not induce a significant increase in search times

668 and/or of the number of gazes directed to non-target words, as they did in Léger et al. (2012)
669 and Vibert et al. (2019). This could be due to the mode of presentation of words in the search
670 display, since in Léger et al.'s and Vibert et al.'s studies the target words were searched within
671 vertical lists of words, whereas random displays were used in this study. Indeed, Dampuré et
672 al. did not find any significant impact of semantic distractors on search times for adult
673 participants searching through random displays of words. However, there was also a
674 discrepancy with Dampuré et al.'s findings, in which semantic distractors attracted more gazes
675 than neutral distractors and filler words, because in the present findings semantic distractors did
676 not attract attention significantly more than other words. This discrepancy may result from the
677 fact that in Dampuré et al., adult participants were mostly university students, who may have
678 particularly high literacy skills, while in this study adult participants were recruited from the
679 general population with varied educational levels. Several authors demonstrated that variability
680 of literacy skill in adulthood was associated with differences in lexically driven eye-movement
681 control during reading (Payne et al., 2020). Veldre and Andrews (2015) suggested that readers
682 with higher quality lexical representations were more likely to extract lexical information from
683 a word before it is fixated. Hence, in the present situation, semantic distractors might only have
684 an impact on visual search for people having high quality lexical representations.

685

686 **Modulation of the impact of induction tasks as a function of age group and type of** 687 **distractors present in the search display**

688 Eye movement data revealed that the impact of induction tasks was not the same for all
689 groups of participants, and that, as hypothesized (H2), the impact of semantic distractors varied
690 according to the induction task performed on the target word.

691 Firstly, the increase in the number of gazes observed after performing the semantic
692 rather than the perceptual task was stronger for neutral displays than for orthographic or

693 semantic displays in fifth and seventh graders, whereas the reverse was true for ninth graders
694 and adults. For the youngest adolescents, performing the semantic task may have led
695 participants to gaze at each word in the display to try to get its meaning even when the words
696 did not share any feature with the target word, resulting in a particularly strong increase in the
697 number of gazes in neutral displays. Ninth graders and adults, by contrast, were able to more
698 easily reject the non-target words that did not share any feature with the target word using their
699 parafoveal/peripheral vision, potentially because of the better quality of their lexical
700 representations. Therefore, performing the semantic induction task may have encouraged them
701 to have more systematic access to the meaning of a more restricted set of words, i.e., the
702 orthographic and semantic distractors that shared features with the target word. In addition, the
703 ninth graders' and adults' data support the hypothesis (H2) that performing the semantic task
704 rather than the perceptual one increased the impact of semantic distractors on the attentional
705 guidance process.

706 Secondly, the impact of the semantic task on the duration of gazes directed to non-target
707 words progressively increased with age. Indeed, performing the semantic task did not have any
708 significant impact on fifth graders' gaze durations, whereas it induced a large increase in gaze
709 durations in ninth graders and adults. Because of their lower word decoding abilities (Perfetti,
710 1992; Plaut & Booth, 2000; Stanovich, 1980), fifth graders may need to access the meaning of
711 distractor words to reject them even after performing the perceptual task or in the absence of
712 any induction task. This would explain why, for them, performing the semantic task did not
713 induce any significant increase in gaze durations. For the older participants, by contrast,
714 performing the semantic rather than the perceptual task guided participants towards processing
715 more deeply than necessary the non-target words, thus increasing the duration of their gazes.

716 Thirdly, whatever the participants' age, the impact of the semantic task on the duration
717 of gazes directed to non-target words was greater for semantic displays than for neutral or

718 orthographic displays. Performing the semantic induction task, as expected (H2), potentiated
719 the impact of semantic distractors on the distractor rejection process by increasing the
720 interference between semantic distractors and the target word. However, performing the
721 perceptual induction task did not increase the impact of orthographic distractors, maybe because
722 when the target word is known in advance, orthographic distractors are already maximally
723 salient even when no induction task is performed.

724

725 **Impact of lexical quality scores on visual search for words**

726 In accordance with hypothesis 4, the increase in visual search efficiency with age was
727 strongly related to the progressive increase in the quality of adolescents' lexical representations.
728 Indeed, participants' lexical quality scores explained 43% of the variance in search times
729 independently of participants' age. Interestingly, the decrease in participants' search times
730 associated with higher lexical quality scores appeared to result more from a decrease in the
731 duration of gazes directed to non-target words than from a decrease in their number. Hence,
732 making a flexible use of the different word processing pathways that may be used to access
733 lexical representations would have an impact on visual search efficiency primarily by
734 shortening the time needed to reject the distractor words sharing features with the target word.
735 Better lexical quality scores also allowed participants to more easily reject non-target words
736 without fixating them directly, i.e., using parafoveal/peripheral vision, but this facilitation of
737 attention guidance had a weaker impact on visual search efficiency.

738

739 **Implications for visual search in more complex verbal environments**

740 As expected, in the simple visual search task used in the present study, fostering access
741 to the lexical representations of words through meanings slowed down visual search, because
742 accessing the meaning of non-target words was not necessary and delayed their rejection.

743 However, fostering semantic word processing through semantic induction tasks could in
744 contrast have a beneficial impact on information search and use in more complex verbal
745 environments where the meaning of words must be accessed to find task-relevant information.
746 Performing semantic induction tasks may for instance facilitate visual search for answers to
747 inferential questions in texts by helping adolescents consider the meaning of the text. The strong
748 impact of semantic induction tasks observed in this study suggests that such tasks may be a
749 powerful tool to facilitate verbal information search in more ecologically-valid situations where
750 the exact wording of the information to find is unknown.

751 One limitation of the current work is that in daily life, people do not often search for
752 single words through random word displays, which questions the generalizability of the data.
753 Rouet et al. (2011) demonstrated that reading a short text about the search topic before
754 performing a Web-like search helped young adolescents to select semantically relevant menu
755 entries. This suggests that semantic induction tasks may also facilitate information search in
756 this situation. However, the extent to which performing semantic induction tasks before
757 searching for verbal information in more diverse natural contexts will actually help adolescents
758 and/or adults to locate what they are looking for is difficult to anticipate, and further
759 experiments must be done to substantiate these claims, e.g., with texts or webpages.

760 Another limitation of this work is that this study evaluated the impact of the semantic
761 induction task in comparison with that of a perceptual task, and not with a situation where no
762 induction task was performed. Hence, no firm conclusion can be reached on whether the impact
763 of the semantic task would be as important in comparison with the typical situation where no
764 induction task is performed. However, as stated above, whereas performing the semantic task
765 potentiated the impact of semantic distractors as expected, performing the perceptual task *did*
766 *not* increase the impact of orthographic distractors. This suggests that the impact of the

767 perceptual task was rather minimal, and that performing the perceptual task might be quite
768 comparable to performing no induction task at all.

769 Altogether, in accordance with the main hypothesis of this work, performing the
770 semantic induction task increased the time needed to find the target word relative to the
771 perceptual one. The induction task impacted both the processes involved in the rejection of
772 distractor words and the “automatic” attention guidance processes that determine which words
773 are gazed at in the search display. Hence, the present study demonstrates that Kiefer and
774 Martens’ attentional sensitization theory may be applied to more complex verbal tasks than
775 simple lexical decision.

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785 Conflicts of interest

786 The authors declare that the research was conducted in the absence of any commercial or
787 financial relationships that could be construed as a potential conflict of interest

788 Ethics approval

789 All procedures performed in studies involving human participants were in accordance with the
790 ethical standards of the institutional and/or national research committee and with the 1964
791 Helsinki Declaration and its later amendments or comparable ethical standards. At the time the

792 experiment was conducted, full review and approval of the study by an ethics committee or an
793 Institutional Review Board was not required according to institutional and national guidelines
794 and regulations.

795 **Consent to participate**

796 Informed consent was obtained from all individual participants included in the study and from
797 their legal guardians.

798 **Consent for publication**

799 Not applicable

800 **Availability of data and materials**

801 The datasets generated during and/or analyzed during the current study are available from the
802 corresponding author on reasonable request.

803 **Code availability (software application or custom code)**

804 Not applicable

805 **Authors' contributions**

806 NV, JB, CR, and J-FR conceived and designed the study and the experimental material. NV,
807 JB, DD, and CR conducted the experiments and analyzed the data. DD and NV wrote the first
808 draft of the manuscript. J-FR made substantial contributions to the interpretation of the data and
809 wrote sections of the manuscript. All authors contributed to manuscript revision, read, and
810 approved the submitted version.

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References

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- 814 Boettcher, S. E. P., & Wolfe, J. M. (2015). Searching for the right word: Hybrid visual and
815 memory search for words. *Attention, Perception & Psychophysics*, *77*, 1132-1142. doi:
816 10.3758/s13414-015-0858-9
- 817 Boot, I., & Pecher, D. (2008). Word recognition is affected by the meaning of orthographic
818 neighbours: Evidence from semantic decision tasks. *Language and Cognitive Processes*,
819 *23*, 375–393. doi:10.1080/01690960701527317
- 820 Carreiras, M., Perea, M., & Grainger, J. (1997). Effects of orthographic neighborhood in visual
821 word recognition. *Journal of Experimental Psychology: Learning, Memory, and*
822 *Cognition*, *23*, 857–871. doi:10.1037/0278-7393.23.4.857
- 823 Coltheart, M., Rastle, K., Perry, C., & Langdon, R. (2001). DRC: a dual route cascaded model
824 of visual word recognition and reading aloud. *Psychological Review*, *108*, 204–256. doi:
825 10.1037/0033-295X.108.1.204
- 826 Dampuré, J., Ros, C., Rouet, J.-F., & Vibert, N. (2014). Task-dependent sensitisation of
827 perceptual and semantic processing during visual search for words. *Journal of Cognitive*
828 *Psychology*, *26*, 530-549. doi: 10.1080/20445911.2014.907576
- 829 Deltour, J. J. (1993). Echelle de vocabulaire Mill Hill de J. C. Raven : Adaptation française et
830 normes comparées du Mill Hill et du Standard Progressive Matrices (PM38). Manuel et
831 Annexes. Braine le Château, Belgique : Application des Techniques Modernes.
- 832 Heil, M., Rolke, B., & Pecchinenda, A. (2004). Automatic semantic activation is no myth.
833 *Psychological Science*, *15*, 852–857. doi:10.1111/j.0956-7976.2004.00766.x
- 834 Hirsh, S. G. (2000). Children's relevance criteria and information seeking on electronic
835 resources, *Journal of the American Society for Information Science*, *50*, 1265-1283.
- 836 Huettig, F., Olivers, C. N. L., & Hartsuiker, R. J. (2011). Looking, language, and memory:
837 Bridging research from the visual world and visual search paradigms. *Acta Psychologica*,
838 *137*, 138–150. doi:10.1016/j.actpsy.2010.07.013

- 839 Kaakinen, J. K., Lehtola, A., & Paattilammi, S. (2015). The influence of a reading task on
840 children's eye movements during reading. *Journal of Cognitive Psychology*, *27*(5), 640–
841 656. doi:10.1080/20445911.2015.1005623
- 842 Kiefer, M., & Martens, U. (2010). Attentional sensitization of unconscious cognition: Task sets
843 modulate subsequent masked semantic priming. *Journal of Experimental Psychology:*
844 *General*, *139*(3), 464-489. doi: 10.1037/a0019561
- 845 Kiefer, M. (2012). Executive control over unconscious cognition: Attentional sensitization of
846 unconscious information processing. *Frontiers in Human Neuroscience*, *6*, 61. doi:
847 10.3389/fnhum.2012.00061.
- 848 Lambert, E., & Chesnet, D. (2001). NOVLEX. A lexical database for elementary school
849 students. *L'Année Psychologique*, *101*, 277–288. doi: 10.3406/psy.2001.29557
- 850 Lefavrais, P. (1968). *La Pipe et le Rat. L'évaluation du savoir-lire du cours préparatoire à*
851 *l'enseignement supérieur et le facteur d'éducabilité PI* [The Pipe and the Rat. The
852 evaluation of reading proficiency from 1st grade to university and the educability factor
853 PI]. Issy-Les-Moulineaux (France) : Edition et Application Psychologique.
- 854 Léger L., Rouet J.-F., Ros C., & Vibert N. (2012). Orthographic versus semantic matching in
855 visual search for words within lists. *Canadian Journal of Experimental Psychology*, *66*,
856 32-43. doi: 10.1037/a0026111
- 857 Lété, B., Sprenger-Charolles, L., & Colé, P. (2004). MANULEX: A grade-level lexical
858 database from French elementary school readers. *Behavior Research Methods,*
859 *Instruments & Computers*, *36*, 156-166.
- 860 Nation, K. (2009). Form–meaning links in the development of visual word recognition.
861 *Philosophical Transactions of the Royal Society B*, *364*, 3665–3674.
- 862 Ojanpää, H., Näsänen, R., & Kojo, I. (2002). Eye movements in the visual search of word
863 lists. *Vision Research*, *42*, 1499-1512.

- 864 Payne, B. R., Federmeier, K. D., & Stine-Morrow, E. A. L. (2020). Literacy skill and intra-
865 individual variability in eye-fixation durations during reading: Evidence from a diverse
866 community-based adult sample. *Quarterly Journal of Experimental Psychology*, *73*(11),
867 1841-1861.
- 868 Perfetti, C. A. (1992). The representation problem in reading acquisition. In P. B. Gough, L. C.
869 Ehri, & R. Treiman (Eds.), *Reading Acquisition* (pp. 145-174). Hillsdale, New Jersey,
870 USA: Erlbaum.
- 871 Perfetti, C. A. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of*
872 *Reading*, *11*, 357-383.
- 873 Perfetti, C. A., & Hart, L. (2002). The lexical quality hypothesis. In L. Verhoeven, C. Elbro, &
874 P. Reistma (Eds.), *Precursors of functional literacy* (pp. 189-213). Amsterdam: John
875 Benjamins Publishing Company. doi: 10.1075/swll.11.14per
- 876 Perfetti, C., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension.
877 *Scientific Studies of Reading*, *18*, 22-37. doi: 10.1080/10888438.2013.827687
- 878 Pew Research Center (2018). *How teens and parents navigate screen time and device*
879 *distractions*. Retrieved from [https://www.pewresearch.org/internet/2018/08/22/how-](https://www.pewresearch.org/internet/2018/08/22/how-teens-and-parents-navigate-screen-time-and-device-distractions/)
880 [teens-and-parents-navigate-screen-time-and-device-distractions/](https://www.pewresearch.org/internet/2018/08/22/how-teens-and-parents-navigate-screen-time-and-device-distractions/), July 27, 2022.
- 881 Plaut, D. C., & Booth, J. R. (2000). Individual and developmental differences in semantic
882 priming: Empirical and computational support for a single-mechanism account of lexical
883 processing. *Psychological Review*, *107*, 786-823.
- 884 Potocki, A., Ros, C., Vibert, N., & Rouet, J.-F. (2017). Children's visual scanning of textual
885 documents: Effects of document organization, search goals, and metatextual knowledge.
886 *Scientific Studies of Reading*, *21*(6), 480-497. doi: 10.1080/10888438.2017.1334060
- 887 Reichle, E. D., Pollatsek, A., & Rayner, K. (2012). Using E-Z reader to simulate eye movements
888 in nonreading tasks: A unified framework for understanding the eye-mind link.

- 889 *Psychological Review*, 119, 155–185. doi:10.1037/a0026473
- 890 Rodd, J. M. (2004). When do leotards get their spots? Semantic activation of lexical neighbors
891 in visual word recognition. *Psychonomic Bulletin & Review*, 11, 434–439.
892 doi:10.3758/BF03196591
- 893 Rouet, J.-F., Ros, C., Goumi, A., Macedo-Rouet, A., & Dinet, J. (2011). The influence of
894 surface and deep cues on primary and secondary school students' assessment of relevance
895 in Web menus. *Learning and Instruction*, 21, 205-219.
- 896 Schotter, E. R. (2013). Synonyms provide semantic preview benefit in English. *Journal of*
897 *Memory and Language*, 69, 619-633. doi: 10.1016/j.jml.2013.09.002
- 898 Seassau, M., & Bucci, M.-P. (2013). Reading and visual search: A developmental study in
899 normal children. *PLoS ONE*, 8(7), e70261. doi:10.1371/journal.pone.0070261
- 900 Smahel, D., Okkonen, J., Machackova, H., Mascheroni, G., Dedkova, L., Staksrud, E.,
901 Ólafsson, K., Livingstone, S., Hasebrink, U., & Kotilainen, S. (2020). *EU Kids Online*
902 *2020: Survey results from 19 countries*. (EU Kids Online). doi:
903 10.21953/lse.47fdeqj01ofo
- 904 Smith, M. C., Bentin, S., & Spalek, T. M. (2001). Attention constraints of semantic activation
905 during visual word recognition. *Journal of Experimental Psychology: Learning, Memory,*
906 *and Cognition*, 27, 1289–1298. doi:10.1037/0278-7393.27.5.1289
- 907 Soto, D., Heinke, D., Humphreys, G. W., & Blanco, M. J. (2005). Early, involuntary top–down
908 guidance of attention from working memory. *Journal of Experimental Psychology:*
909 *Human Perception and Performance*, 31, 248–261. doi:10.1037/0096-1523.31.2.248
- 910 Stanovich, K. E. (1980). Toward an interactive-compensatory model of individual differences
911 in the development of reading fluency. *Reading Research Quarterly*, 16, 32–71. doi:
912 10.2307/747348
- 913 Thornton, T. L., & Gildea, D. L. (2007). Parallel and serial processes in visual search.

- 914 *Psychological Review*, 114, 71-103. doi: 10.1037/0033-295X.114.1.71
- 915 Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive*
916 *Psychology*, 12, 97–136. doi: 10.1016/0010-0285(80)90005-5
- 917 Van Zoest, W., & Donk, M. (2010). Awareness of the saccade goal in oculomotor selection:
918 Your eyes go before you know. *Consciousness and Cognition*, 19, 861–871. doi:
919 10.1016/j.concog.2010.04.001
- 920 Veldre, A., & Andrews, S. (2015). Parafoveal lexical activation depends on skilled reading
921 proficiency. *Journal of Experimental Psychology: Learning, Memory and Cognition*,
922 41(2), 586-595. doi: 10.1037/xlm0000039
- 923 Verhoeven, L., & Perfetti, C. A. (2011). Introduction to this special issue: Vocabulary growth
924 and reading skill. *Scientific Studies of Reading*, 15, 1-7.
- 925 Verhoeven, L., van Leeuwe, J., & Vermeer, A. (2011). Vocabulary growth and reading
926 development across the elementary school years. *Scientific Studies of Reading*, 15, 8-25.
- 927 Vibert, N., Braasch, J. L. G., Darles, D., Potocki, A., Ros, C., Jaafari, N., & Rouet, J.-F. (2019).
928 Adolescents' developing sensitivity to orthographic and semantic cues during visual
929 search for words. *Frontiers in Psychology*, 10, 642. doi: 10.3389/fpsyg.2019.00642
- 930 Walraven, A., Brand-Gruwel, S., & Boshuizen, H. P. A. (2008). Information-problem solving:
931 A review of problems students encounter and instructional solutions. *Computers in*
932 *Human Behavior*, 24, 623-648.
- 933 Weiss, Y., Katzir, T., & Bitan, T. (2015). The effects of orthographic transparency and
934 familiarity on reading Hebrew words in adults with and without dyslexia. *Annals of*
935 *Dyslexia*, 65(2), 84 – 102. doi: 10.1007/s11881-015-0100-4
- 936 Wylie, J., Thomson, J., Leppänen, P.H.T., Ackerman, R., Kanniainen, L., & Prieler, T. (2018).
937 Cognitive processes and digital reading. In M. Barzillai, J. Thomson, S. Schroeder, & P.
938 van den Broek (Eds.), *Learning to read in a digital world* (pp. 57-90). John Benjamins.

- 939 Wolfe, J. M. (2020). Visual search: how do we find what we are looking for? *Annual Review*
940 *of Vision Science*, 6, 539-562. doi.org/10.1146/annurev-vision-091718-015048
- 941 Wolfe, J. M., Võ, M. L.-H., Evans, K. K., & Greene, M. R. (2011). Visual search in scenes
942 involves selective and nonselective pathways. *Trends in Cognitive Sciences*, 15(2), 77–
943 84. doi:10.1016/j.tics.2010.12.001
- 944 Zelinsky, G. J. (2008). A theory of eye movements during target acquisition. *Psychological*
945 *Review*, 115, 787–835. doi: 10.1037/ a0013118
- 946 Zhang, M., & Quintana, C. (2012). Scaffolding strategies for supporting middle school
947 students' online inquiry processes. *Computers & Education*, 58, 181-196.
- 948 Zhou, W., Mo, F., Zhang, Y., & Ding, J. (2017). Semantic and syntactic associations during
949 word search modulate the relationship between attention and subsequent memory. *The*
950 *Journal of General Psychology*, 144(1), 69-88. doi: 10.1080/00221309.2016.1258389
- 951