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Semantic priming in French children with varying comprehension skills

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Semantic priming was analysed in two groups of French children contrasted on comprehension skills with a visual lexical-decision task using a long SOA (800 ms). Two relation types between related primes and targets were examined: pure semantic relation (categorical vs. functional), and lexical association strength (strong vs. weak). Targets were preceded by related, unrelated, and neutral primes. Skilled comprehenders showed semantic priming only for category-related words, whatever their association strength, and without any evidence of an associative boost. Less-skilled comprehenders also showed semantic priming for category-related words, irrespective of their association strength, but with an indication of an associative boost. They also displayed semantic priming for function-related words that are strongly associated, but not for those that are weakly associated. These results are discussed within the theoretical frame proposed by Plaut and Booth (2000).

Keywords: Semantic memory development; Comprehension skills; Pure semantic relation; Lexical association strength; Visual lexical-decision task; Semantic priming paradigm.

INTRODUCTION

How does semantic priming affect word processing in children while reading? Is it similar in children with varying comprehension skills? The main goal of the present study was to investigate the dynamics of

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computing noun meaning in two groups of French children contrasted on comprehension skills (skilled comprehenders vs. less-skilled comprehenders) with a visual lexical-decision task.

Since Meyer and Schvaneveldt's research (1971), many studies have examined the effect of the semantic relation between two concepts on semantic priming. It occurs for word pairs that are either purely semantically related (e.g., category or function related) or associatively related in a variety of tasks, including both lexical decision and word naming (Becker, 1980; Meyer, Schvaneveldt, & Ruddy, 1975).

Lexical association strength is classically conceived as resulting from temporal contiguity in speech or text (McKoon & Ratcliff, 1992), or word co-occurrence within proposition (McNamara, 1992). By contrast, pure semantic relatedness is commonly defined and measured as feature overlap, and has given rise, in recent years, to an increasing amount of research. Most of these studies have used the semantic priming paradigm, and concerned adults (see McNamara, 2005; Neely, 1991, for reviews).

One of the issues examined in the semantic priming studies aims at determining if semantic priming is due to lexical association strength or feature overlap (see Hutchison, 2003; Lucas, 2000, for meta-analytic reviews). Among other problems, researchers have to deal with the difficulty in separating these two semantic relations. Although it has been hypothesized that association norms reflect primarily the clausal contiguity between items, they also contain other types of semantic relations (e.g., Moss, Ostrin, Tyler, & Marslen-Wilson, 1995). Two words can be associated in many ways. They can be synonyms, antonyms, members of the same natural or artificial category; a perceptual or functional property can connect them, and so on. Nevertheless, Lucas (2000) concluded that, among adults, there is strong evidence of an overall pure semantic priming effect in automatic semantic priming, which can then occur without association. Hutchison (2003) proposed very different conclusions and underlined that automatic priming is due to both association strength and feature overlap.

Regarding semantic priming in children, a number of studies have shown that a word is identified more rapidly when it is presented in a related context rather than in an unrelated context; an age-related decrease in context effects has also been evidenced (e.g., McCauly, Weil, & Sperber, 1976; Schvaneveldt, Ackerman, & Semlear, 1977; Simpson & Lorsbach, 1983). However, no semantic priming effect was exhibited at short SOAs (SOA: Stimulus Onset Asynchrony) in younger children. For example, in a cross-sectional study examining the effect of meaning frequency of homophones with a lexical-decision priming task at a 250 ms SOA, Nievas and Justicia (2004) indicated that priming effect was absent in fifth and eighth graders, whereas it was present in the first and third years of secondary, and in the first year of university. Additionally, in a study comparing semantic and phonological priming in the Korean language, a transparent orthographic system, Kang and Simpson (1996) found that sixth graders, but not second graders, displayed semantic priming at a 500 ms SOA.

To sum up, younger children benefit more from semantic priming than older children or adults. Indeed, semantic priming decreases in the developmental course as children become more proficient in reading. By contrast, at short SOAs, no semantic priming is exhibited in younger children.

Semantic priming might also differ according to comprehension skills. Cain and Oakhill (2004) pointed out that few studies have examined this question at the word level. Nation and Snowling (1999) analysed developmental differences in sensitivity to semantic relations among skilled and less-skilled comprehenders, matched on decoding skill (all children had normal decoding skill) and chronological age (10–11 years). Their investigation is important for all researchers examining the contribution of pure semantic relatedness and associative strength in semantic priming since these workers were the first to disentangle their respective influence, by manipulating both pure semantic relatedness (categorical vs. functional) and associative relatedness (associated vs. non-associated). However, their research did not concern word reading. Indeed, they used an auditory lexical-decision priming task associated to a single word-presentation method, which required a lexical decision about all auditory items, both primes and targets. Their results showed differences between skilled and less-skilled comprehenders. Nevertheless, the respective role of pure semantic relatedness and associative strength in semantic priming remains to be studied in children with varying comprehension skills while word reading.

Plaut and Booth (2000) developed a very interesting model to account for semantic priming in children and adults while word reading. In their distributed connectionist network, each concept is represented by a particular pattern of activity over a large number of processing units. In processing a word, units co-operate and compete across weighted connections until the network as a whole settles into a stable pattern of activity that represents the meaning of the word. In semantic priming, the authors hypothesized that at short SOAs there is facilitation dominance for both categorical and associative priming, whereas at long SOAs there is facilitation dominance for associative priming, but inhibition dominance for categorical priming (see also Plaut, 1995). Categorical facilitation tends to be weak because only some features overlap between the prime and the target, whereas categorical inhibition tends to be strong because many features do not overlap (for example, cats and dogs are members of the same superordinate category—the mammals—since they possess similar features;

but at the same time, they differ in many aspects). Their research gave support to a single-mechanism distributed network account, which implies that children and adults should differ only quantitatively in semantic priming. For example, because children have less reading experience than adults, the reading process needs more time. Children are then less effective than adults at processing a prime exposed briefly. Consequently, a longer SOA in children may result in the same degree of activation in the semantic system as a shorter SOA in adults. In their empirical studies, the prime–target pairs were strongly associated, but were not controlled on categorical relation. Third graders, sixth graders, and adults performed a visual lexical-decision priming task. Priming effects were evaluated by contrasting related, unrelated, and neutral (non-word) priming contexts. Neutral priming was added insofar as it allows establishing explicitly the magnitude of facilitation and inhibition by comparing decision latencies (DLs) to target words following neutral primes to those following related and unrelated primes. Results showed that the magnitude of priming effects is influenced not only by stimulus and experimental factors, but also by individual differences in age and reading ability. Very briefly, in adults, priming effects at a long SOA (800 ms) were due to a combination of facilitation from related primes and inhibition from unrelated primes, whereas at a brief SOA (200 ms), they reflected facilitation only. In children, at the long SOA, they resulted from facilitation to related primes, but not from inhibition to unrelated primes. Thus, at a long SOA, only facilitation was exhibited in children.

The empirical contribution reported in this paper aimed to examine semantic priming in French skilled and less-skilled comprehenders while word reading, by considering the theoretical frame proposed by Plaut and Booth (2000). Specifically, it tested the effect of pure semantic relatedness by examining a prediction derived from Plaut and Booth's hypotheses: since more features overlap for category-related words (e.g., *fraise–framboise*, *strawberry–raspberry*) than for function-related words (e.g., *berceau–bébé*, *cradle–baby*), facilitation would be higher for the former than for the latter. This study was also designed to test the robust effect of association strength in children while word reading.

Following Nation and Snowling's study (1999), four semantically related prime–target pair types were proposed: category-related and strongly associated words (e.g., *chien–chat*, *dog–cat*), category-related and weakly associated words (e.g., *tulipe–rose*, *tulip–rose*), function-related and strongly associated words (e.g., *ruche–abeille*, *hive–bee*), and function-related and weakly associated words (e.g., *balai–sorcière*, *broom–witch*). Following Plaut and Booth's procedure, participants performed a visual lexical-decision priming task according to three priming contexts: related, unrelated, and neutral (non-word) priming conditions. A long SOA (800 ms) was only used since researchers (e.g., Kang & Simpson, 1996; Nievas & Justicia, 2004;

Plaut & Booth, 2000) underlined difficulties to evidence priming effects at short SOAs in young children.

METHOD

Participants

Eighty fourth-graders (aged from 9.6 to 10.5 years) were tested individually in order to set up two groups of children contrasted on comprehension skills. They attended four primary schools in the suburb of Lille (North of France) serving socially mixed catchments, with a majority of middle to low socioeconomic level. Measures of decoding, non-verbal ability, and syntactic comprehension served as selection tests. Among these eighty fourth-graders, thirty-six children aged 10 years 3 months participated in this study (16 girls and 20 boys): 18 skilled comprehenders and 18 less-skilled comprehenders. No participants were reading impaired.

Selection tests

Decoding. Two tests were used for assessing decoding skill. In the *Alouette* standard test (Lefavrais, 1967), children had to read a text aloud. The final score took into account both speed (how many words were read during three minutes) and accuracy (errors were taken into account). In addition, children had to read a list of 20 pseudo-words (from Casalis, 1995).

Non-verbal ability. Raven's Coloured Progressive Matrices (Raven, 1976) served as non-verbal ability measures.

Children who performed below the 25th percentile on either decoding or non-verbal ability tests were excluded from the study.

Syntactic comprehension. Listening comprehension skill was assessed with a part of the syntactic comprehension *ECOSSE* test (Lecocq, 1996), and a comprehension task of sentences constructed with a relative clause (Casalis & Leuwers, 2005). In the *ECOSSE* test, children heard an auditory sentence and were then presented with four pictures. Children had to point out the picture corresponding to the sentence. In the present study, children were presented with the last 16 items. The comprehension task of sentences constructed with a relative clause was composed with 12 auditory sentences constructed with a subject–object relative clause (e.g., *la reine que le pirate attache est blonde*, *the queen the pirate ties is blond*). As in the *ECOSSE* test, comprehension was assessed with the choice of one among four pictures (e.g., pictures combining a pirate and a queen, one of the character tying the other, crossed with being blond). A global score (on 28 items) was computed by adding correct responses in both tests (16 items and 12 items). The median of this score served to distinguish children according to their whole comprehension score. According to the *ECOSSE* norms, the scores of skilled comprehenders fall into normal range, while those of less-skilled comprehenders fall below the 25th percentile.

Additional tests measured semantic processing, reading comprehension, and choice reaction time.

Additional tests

Semantic processing. In the semantic fluency task, children were asked to produce the greatest number of words during 90 seconds, successively for the "sport" and "holidays" categories.

Reading comprehension. The L4 test (Lobrot, 1973) was administered. Children read a text for five minutes. Once the text had been removed, they were questioned. Answering questions necessitated remembering some aspects of the text, but no causal reasoning. The test was not timed and the score was response accuracy.

Choice reaction time. Since the analyses of our empirical contribution mainly rested on decision latencies in a visual lexical-decision task, it was then necessary to assess reaction time in a two-forced-choice task. Thus, a choice reaction time task was proposed. Participants were tested individually. Thirty trials were displayed on a 15″ XGA monitor controlled by a DELL Inspiron 12600 computer (1200 MHz) using Media Control Function (MCF 4.0) software. A trial consisted of a fixation point "X" presented in the centre of the screen for 2000 ms, followed by a yellow or red point, which remained on the screen until the response. The inter-trial interval (ITI) was 2000 ms. Participants were told to respond by pressing one of two buttons on an "azerty" keyboard ("p" for "yellow point" and "a" for "red point" for right-handed participants, and the reverse for left-handed participants). There were 50% "yellow point" and 50% "red point" trials. Eight practice trials preceded the thirty test trials. Reaction times and responses were recorded. Trials on which an error occurred were removed from the analysis.

Results for the different tests are presented in Table 1.

Two groups, each with eighteen children, were contrasted on comprehension skills: skilled comprehenders versus less-skilled comprehenders. Both groups were strictly matched on chronological age, decoding skill (*Alouette* reading age and pseudo-word reading), and choice reaction time. By contrast, skilled comprehenders outperformed less-skilled comprehenders in

TABLE 1
Mean scores (standard deviations) of skilled and less-skilled comprehenders on selection and additional tests

Tests	*Comprehenders*		
	Skilled	*Less-skilled*	*F(1, 34)*
Chronological age in months	123.67 (6)	123.11 (8.61)	<1
Decoding:			
Alouette reading age (in months)	120.94 (9.84)	119.28 (10.11)	<1
Pseudo-word reading (max: 20)	17.28 (2.02)	17.22 (2.18)	<1
Non-verbal ability:			
Raven's Progressive Matrices (max: 36)	30.5 (3.13)	27.61 (3.85)	6.098*
Listening comprehension:			
Syntactic comprehension (max: 28)	25.17 (2.07)	16.11 (3.31)	97.155^{+}
Semantic processing:			
Semantic fluency task	20.06 (4.35)	16.67 (5.30)	4.399*
Reading comprehension:			
L4 test (max: 10)	6.56 (2.04)	4.89 (2.08)	5.894*
Choice reaction time (in ms)	464.15 (55.53)	498.65 (75)	2.461

Note: $^*p < .05$; $^+p < .0001$.

listening comprehension skill (syntactic comprehension), semantic processing (semantic fluency task), and reading comprehension (in the L4 test, 72% of skilled comprehenders were in the quartiles 1 and 2, whereas 67% of less-skilled comprehenders were in the quartiles 3 and 4). It was not possible to match both groups on non-verbal ability (Raven's progressive matrices). However, the difference between both groups was slight, and children who performed below the 25th percentile were not included in the study. In addition, according to their teachers, no children were dyslexic, or had cognitive impairments or severe learning difficulties.

The visual lexical-decision task

Materials. To select appropriate materials for children, we used the Novlex database (Lambert & Chesnet, 2001) and normative lists of word associations for French language used in adults[1] (Ferrand & Alario, 1998). From these two databases, 60 word pairs were selected to represent the four

[1]We could not exploit the database of word association norms developed by de La Haye (2003) for French language used in children and adults. Indeed, this database concerns only 200 words (belonging to different grammatical categories: 148 nouns, 28 verbs, 24 adjectives), and was then too much restricted for selecting a sufficient number of nouns under our four conditions.

types of word pairs resulting from the cross-classification of pure semantic relatedness (categorical- vs. functional-related words) and association strength (mean association strength: 38.65% for strongly associated words, and 4.83% for weakly associated words). Thus, there were fifteen pairs in each cell (Appendix 1).

From these 60 word pairs, three lists were constructed so that each target was associated with the three priming contexts: related, unrelated, and neutral priming contexts. Because of the constraints of the selection of materials, frequency and letter number could not be strictly matched across conditions. However, prime–target pairs were selected such that the three primes paired with a target had the same letter number in the different priming contexts. Each list was composed of 120 prime–target pairs: 60 pairs with word targets, and 60 pairs with non-word targets. The 60 word targets were preceded by 20 neutral primes (non-words), 20 unrelated word primes, and 20 related word primes (5 items for each of the four following cells: category-related and strongly associated, category-related and weakly associated, function-related and strongly associated, and function-related and weakly associated). The 60 non-word targets were preceded by 30 different word primes and 30 different non-word primes. There were also 24 practice trials constructed with the same constraints. The practice trials were excluded from all statistical analyses.

Procedure. Participants were tested individually at a long SOA (800 ms). They viewed all stimuli for the priming task on a 15″ XGA monitor controlled by a DELL Inspiron 12600 computer (1200 MHz) using Media Control Function (MCF 4.0) software. All stimuli were presented in black lowercase letters on a grey background on the computer monitor placed about 50 cm in front of the participant. A priming trial consisted of a fixation point "X" displayed in the centre of the screen for 2000 ms, followed by the prime for 600 ms, then an inter-stimulus interval (ISI) for 200 ms, and finally the target, which remained on the screen until the participant responded. The inter-trial interval (ITI) was 2000 ms. The three priming contexts for the critical prime–target pairs were counterbalanced between participants. Specifically, a related prime, an unrelated prime, and a neutral prime preceded the same target word equally often across three different experimental lists. Because three counterbalancing lists were used, a single participant never saw the same stimulus item on more than one occasion. Order of trials was randomized for each participant within each list. Participants were instructed to read or identify the "first letter string" (the prime) silently and to decide as quickly and accurately as possible whether "the second letter string" (the target) was a legitimate French word or not. Participants responded by pressing one of two buttons on an "azerty" keyboard ("p" for yes and "a" for no for right-handed participants, and the reverse for left-handed participants). There were 50% "word" and 50% "non-word" trials. The proportion of related trials was 0.33 when the target was a word (0.166 of the experimental trials). Three rest periods were provided during the experimental trials. Lexical decision latencies were recorded as the time between the onset of the target and the participant's response. Responses were also recorded. It took about ten minutes to complete the task.

Design. The dependent measures were decision latency and accuracy. In all subsequent analyses of variance (ANOVAs), Group (skilled comprehenders vs. less-skilled comprehenders) was a between-subjects factor, whereas Relation Type (categorical vs. functional), Association Strength (strong vs. weak), and Priming Context (neutral, unrelated, related) were within-subjects factors.

RESULTS

In all decision latency analyses reported in this article, trials on which an error occurred were excluded. In addition, latencies greater or less than 2.5 standard deviations from the mean in each condition for either the skilled comprehenders or the less-skilled comprehenders were replaced by the cut-off value. This procedure affected 2.98% of the scores (2.69% for skilled comprehenders, 3.28% for less-skilled comprehenders).

Global analysis

The DLs analysis. The skilled comprehenders were 45 ms faster than the less-skilled comprehenders (907 ms and 952 ms, respectively), but this difference did not attain statistical significance, $F < 1$. There was a main effect of priming context, $F(2, 68) = 11.536$, $MSE = 23623.224$, $p < .001$. In comparison with neutral priming ($M = 962$ ms), there was a very small facilitation with unrelated priming ($M = 946$ ms, $d = 16$ ms), but a high facilitation with related priming ($M = 880$ ms, $d = 82$ ms), giving a benefit of 66 ms for this last priming context, $F = 13.212$, $p < .01$. There was a main effect of association strength, with DLs being 63 ms faster on strongly associated words ($M = 898$ ms) than on weakly associated words ($M = 961$ ms), $F(1, 34) = 32.826$, $MSE = 13249.9$, $p < .001$. By contrast, there was no main effect of relation type, $F < 1$. Additionally, there were a two-way Relation Type × Association Strength interaction, $F(1, 34) = 4.314$, $MSE = 23760.512$, $p < .05$, and a two-way Relation Type × Priming Context interaction, $F(2, 68) = 3.913$, $MSE = 20886.312$, $p < .05$, but no significant interaction between association strength and priming context, $F < 1$. Finally, the three-way Relation Type × Association Strength × Priming Context interaction was marginally significant, $F(2, 68) = 2.953$, $MSE = 10718.391$, $p = .0589$.

The errors analysis. This yielded a main effect of priming context, $F(2, 68) = 6.713$, $MSE = 0.008$, $p < .01$. In comparison with neutral priming ($M = 4.9\%$) and unrelated priming ($M = 5\%$), fewer errors were made with related priming ($M = 1.5\%$), $F = 13.409$, $p < .01$. There was also a main effect of association strength, with 2% fewer errors on strongly associated words ($M = 2.8\%$) than on weakly associated words ($M = 4.8\%$), $F(1, 34) = 6.428$, $MSE = 0.007$, $p < .05$. No other main effects or interactions approached statistical significance.

This global analysis did not provide evidence of significant differences in decision latencies between both groups, which were paired on normal decoding skill. By contrast, it revealed priming context effects, which were modulated by the relation type and the association strength. A second step of analysis was then carried out to highlight more finely differences in semantic priming between both groups, and to discuss the results in each group, for categorical relations and functional relations separately (see Table 2 and Appendix 2). Planned comparisons also completed these analyses.

TABLE 2
Mean lexical decision latencies in ms (error percents) for skilled and less-skilled comprehenders at a long SOA (800 ms) according to relation type, association strength, and priming context; and priming effects

Relation Type × Association Strength	*Priming context*			*Priming effects*		
	Neutral	*Unrelated*	*Related*	*N–U*	*N–R*	*U–R*
Skilled comprehenders						
Categorical–Strong	969 (3.3)	856 (3.3)	813 (1.1)	113 (0)	156 (2.2)	43 (2.2)
Categorical–Weak	944 (4.4)	969 (3.3)	822 (3.3)	−25 (1.1)	122 (1.1)	147 (0)
Functional–Strong	854 (3.3)	891 (5.6)	896 (2.2)	−37 (−2.3)	−42 (1.1)	−5 (3.4)
Functional–Weak	975 (6.7)	954 (4.4)	939 (1.1)	21 (2.3)	36 (5.6)	15 (3.3)
Less-skilled comprehenders						
Categorical–Strong	995 (2.2)	976 (4.4)	842 (1.1)	19 (−2.2)	153 (1.1)	134 (3.3)
Categorical–Weak	997 (10)	999 (7.8)	917 (2.2)	−2 (2.2)	80 (7.8)	82 (5.6)
Functional–Strong	929 (3.3)	916 (2.2)	833 (1.1)	13 (1.1)	96 (2.2)	83 (1.1)
Functional–Weak	1035 (5.6)	1005 (8.9)	977 (0)	30 (−3.3)	58 (5.6)	28 (8.9)

Note: N = neutral priming; U = unrelated priming; R = related priming.

Processing of categorical relations by skilled comprehenders

There was a main effect of priming context, $F(2, 34) = 20.282$, $MSE = 8908.689$, $p < .001$. In comparison with neutral priming ($M = 956$ ms), there was facilitation with unrelated priming ($M = 912$ ms, $d = 44$ ms) and related priming ($M = 818$ ms, $d = 138$ ms), but related priming was 94 ms faster than unrelated priming, $F = 18.19$, $p < .001$. There was no main effect of association strength ($M = 879$ ms for strongly associated words, $M = 912$ ms for weakly associated words, $d = 33$ ms), $F(1, 17) = 1.195$, $MSE = 23423.937$. Finally, there was a two-way Association Strength × Priming Context interaction, $F(2, 34) = 5.404$, $MSE = 8570.035$, $p < .01$. First, on strongly associated words (Table 2), facilitation was displayed for related priming (156 ms), $F = 25.424$, $p < .01$, and unrelated priming (113 ms), $F = 13.303$, $p < .01$. The difference between these two priming contexts (43 ms) was not apparent, $F = 1.946$, but related priming was faster than both neutral and unrelated priming, $F = 13.812$, $p < .01$. Second, on weakly associated words (Table 2), unrelated priming provoked a small inhibition (−25 ms), whereas related priming caused facilitation (122 ms), and was 147 ms faster than unrelated priming, $F = 22.606$, $p < .001$. To sum up, the skilled comprehenders showed semantic priming for category-related words, whatever their association strength. There was no evidence of an associative boost since results did not reveal higher priming for strongly associated words than for weakly associated words. This was essentially due to the fact that the unrelated words provoked a strong priming effect in the category-related and strongly associated words condition.

Processing of categorical relations by less-skilled comprehenders

There was a main effect of priming context, $F(2, 34) = 5.255$, $MSE = 28799.004$, $p < .05$. In comparison with neutral priming ($M = 996$ ms), there was a very minor facilitation with unrelated priming ($M = 987$ ms, $d = 9$ ms), but a high facilitation with related priming ($M = 880$ ms, $d = 116$ ms), giving a benefit of 107 ms for this last priming context, $F = 7.266$, $p < .05$. There was no main effect of association strength ($M = 938$ ms for strongly associated words, $M = 971$ ms for weakly associated words, $d = 33$ ms), $F(1, 17) = 1.301$, $MSE = 22749.218$. To end, the two-way Association Strength × Priming Context interaction did not attain statistical significance, $F < 1$, $MSE = 12965.516$, since priming effects were registered on both association strengths (Table 2). First, on strongly associated words, a little facilitation (19 ms) was registered for unrelated priming, whereas the facilitation with related priming was important

(153 ms), coming out in a benefit of 134 ms for this last priming context, $F = 12.34$, $p < .001$. Second, on weakly associated words, unrelated priming gave no priming effect (−2 ms), whereas related priming involved a facilitation of 80 ms, coming out with a gain of 82 ms for this last priming context, $F = 4.703$, $p < .05$. Thus, in the less-skilled comprehenders, semantic priming was shown for category-related words on both association strengths, and it was numerically higher for strongly associated words than for weakly associated words (134 ms and 82 ms, respectively). So, there was an indication of an associative boost on the category-related words.

Processing of functional relations by skilled comprehenders

There was no main effect of priming context (neutral priming: $M = 914$ ms, unrelated priming: $M = 923$ ms, related priming: $M = 917$ ms), $F < 1$. There was a main effect of association strength, with DLs being 76 ms faster on strongly associated words ($M = 880$ ms) than on weakly associated words ($M = 956$ ms), $F(1, 17) = 8.106$, $MSE = 19066.568$, $p < .05$. The two-way Association Strength × Priming Context interaction was not apparent, $F < 1$. Specifically, related priming did not differ from unrelated priming whatever the association strength (Table 2). First, on strongly associated words, unrelated and related priming contexts gave rise to small inhibitory priming effects (−37 ms and −42 ms, respectively), with no difference between these two priming contexts (−5 ms), $F < 1$. Second, on weakly associated words, unrelated and related priming contexts involved a slight facilitation (21 ms and 36 ms, respectively), and the difference of 15 ms between these two priming contexts was too weak to attain statistical significance, $F < 1$. To sum up, in the skilled comprehenders, no priming effects were displayed on function-related words, whatever their association strength. The DLs were simply quicker on strongly associated words than on weakly associated words.

Processing of functional relations by less-skilled comprehenders

There was no main effect of priming context (neutral priming: $M = 982$ ms, unrelated priming: $M = 960$ ms, related priming: $M = 905$ ms), $F(2, 34) = 1.473$, $MSE = 38464.53$. There was a main effect of association strength, with DLs being 113 ms faster on strongly associated words ($M = 893$ ms) than on weakly associated words ($M = 1006$ ms), $F(1, 17) = 39.178$, $MSE = 8781.103$, $p < .001$. The two-way Association Strength × Priming Context interaction was not apparent, $F < 1$. However, on strongly associated words (Table 2), a very small facilitation was registered with unrelated priming (13 ms), whereas it was relatively high with related priming (96 ms), and the advantage of 83 ms for this last priming context was significant, $F(1, 34) = 4.702$, $MSE = 13125.5$, $p < .05$. On weakly associated words (Table 2), little facilitatory priming effect was registered for either unrelated or related priming (30 ms and 58 ms, respectively), and the difference of 28 ms between these two priming contexts was not apparent, $F < 1$. To sum up, the less-skilled comprehenders showed a priming effect when processing function-related and strongly associated words, but not when processing function-related and weakly associated words. Finally, the DLs were quicker on strongly associated words than on weakly associated words, as in the skilled comprehenders.

DISCUSSION

This study was conducted to determine whether French skilled and less-skilled comprehenders matched for chronological age (10.3 years) and normal decoding skill, but contrasted for comprehension skills, would differ in semantic priming when reading words. Semantic priming was assessed with a visual lexical-decision priming task using a long SOA (800 ms). Priming context was manipulated in order to study the role of two relation types between related primes and targets: pure semantic relation (categorical vs. functional) and association strength (strong vs. weak).

First, in both groups, semantic priming was shown for *category-related words*, irrespective of their association strength. Among the skilled comprehenders, there was no evidence of an associative boost, because of the strong priming effect provoked by the unrelated words in the category-related and strongly associated words condition. Consequently, the semantic priming effect was even higher for the category-related and weakly associated words than for the category-related and strongly associated words (147 ms and 43 ms, respectively). This phenomenon is hard to explain since it only concerned the skilled comprehenders. Among the less-skilled comprehenders, priming on category-related words was numerically higher when they were strongly associated than when they were weakly associated. Thus, there was an indication of an associative boost for category-related words only in the less-skilled comprehenders.

Second, in both groups, the results for *function-related words* showed faster decision latencies on strongly associated words than on weakly associated words, whereas the effect of priming context and the two-way Association Strength × Priming Context interaction were not apparent. However, planned comparisons on the interaction between association strength and priming context indicated different results in both groups.

In the skilled comprehenders, there was no semantic priming for function-related words, whatever their association strength. By contrast, in the less-skilled comprehenders, semantic priming on function-related words was registered for those that were also strongly associated, but not for those that were weakly associated.

These results argue for individual differences in children's real-time printed word processing due to varying comprehension skills. Skilled comprehenders show a high sensitivity to semantic relatedness, with semantic priming effects highlighted for category-related words, but not for function-related words. At the same time, they seem less sensitive to association in context, since the semantic priming effects for category-related words were shown for strongly and weakly associated words. Another pattern characterizes less-skilled comprehenders, for whom semantic priming was evidenced for category-related words, whatever their association strength, but with an indication of an associative boost, and for function-related words, solely when they were also strongly associated. So, less-skilled comprehenders seem sensitive both to semantic relatedness and to association in context.

How to explain these differences in semantic priming between skilled and less-skilled comprehenders? The results of the pre-tests showed that the less-skilled comprehenders were disadvantaged in a variety of comprehension skills, with weaker scores in listening comprehension skill evaluated with syntactic comprehension tasks, in semantic processing estimated with a semantic fluency task, and in reading comprehension assessed with the L4 test (Lobrot, 1973), which undoubtedly also solicited the memory. Regarding working memory, Nation, Adams, Bowyer-Crane, and Snowling (1999) have shown that the spatial spans of less-skilled comprehenders are normal, whereas their verbal spans are impaired. Nation et al. concluded that the memory difficulties associated with poor reading comprehension were specific to language and associated with language impairment, rather than a cause of reading comprehension failure. Thus, their results implied the rejection of the hypothesis that less-skilled comprehenders have general processing capacity limitations, which compromise their reading and language comprehension skills. Indeed, lower spans in less-skilled comprehenders characterize only memory tasks that place a heavy weight on semantic processing skills. An impaired verbal span might then affect a certain type of linguistic unit and impact the activation process of words, which are not strongly associated in context. However, for the moment, that question remains open.

To summarize, our empirical contribution showed semantic priming for category-related words in both groups: skilled and less-skilled comprehenders. By contrast, semantic priming for function-related words was solely evidenced in less-skilled comprehenders' processing of strongly associated words, and it was numerically lower than priming for category-related words. These results give some credit to our proposition derived from Plaut and Booth's hypothesis (2000), suggesting that facilitation would be higher for category-related words than for function-related words because more features overlap for the former than for the latter. Plaut and Booth's model is remarkable since it can account for feature-based priming as well as for associative priming. Their research give some support to a single-mechanism distributed network account, which implies that children and adults should differ only quantitatively in semantic priming. Nonetheless, the difference between skilled and less-skilled comprehenders relative to function-related and strongly associated words remains unexplained. In a quantitative model, more priming on function-related and strongly associated words would be predicted in skilled than in less-skilled comprehenders. The results of our empirical contribution did not conform strictly to this scenario. Further studies manipulating SOAs will be necessary to explain in quantitative terms these differences in semantic priming on function-related words between both groups. At shorter SOAs, semantic priming on function-related words would be displayed in skilled comprehenders. By contrast, at longer SOAs, it would decrease or disappear in less-skilled comprehenders.

In conclusion, our data evidenced that a source of variation across skilled and less-skilled comprehenders comes from semantic activation while reading since the former showed a high sensitivity to the semantic relatedness, whereas the latter were sensitive to both the semantic relatedness and the association strength in context. At present, the same empirical research is conducted in our laboratory (Bonnotte & Casalis, 2007) with young and old adults at long and short SOAs. One aim is to determine if automatic semantic priming in adults is due to association strength or feature overlap. This question gave rise to a lot of studies and the literature in this domain is still searching for a consensus since Lucas (2000) concluded that a pure semantic priming effect in automatic semantic priming can occur without association, whereas Hutchison (2003) underlined that automatic priming appears to be due to both association strength and feature overlap. Manipulating both pure semantic relatedness and association strength permits the disentanglement of their respective influence in semantic priming. If a pure semantic priming effect could be displayed in automatic semantic priming, then it would occur at a short SOA for both strongly and weakly associated words. By contrast, if automatic semantic priming appears to be due to both association strength and feature overlap, then it would occur at a short SOA for strongly associated words, but not for weakly associated words. Finally, the quantitative model developed by

Plaut and Booth (2000) offers an interesting frame to the understanding of results not only in children with varying comprehension skills, but also among young and old adults.

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APPENDIX 1

Neutral primes (non-words), unrelated primes, related primes, and target words used in the visual lexical-decision task

Primes			Target words			
Neutral	*Unrelated*	*Related*		*AS*	*LNP*	*LNT*
		Category-related and strongly associated words				
ric	jeu *game*	coq *cock*	poule *chicken*	56.1	3	5
itêre	arbre *tree*	chien *dog*	chat *cat*	48.3	5	4
mendorge	sonnette *bell*	chenille *caterpillar*	papillon *butterfly*	31.5	8	8
bilécan	endroit *place*	chameau *camel*	dromadaire *dromedary*	24.7	7	10
baute	châle *shawl*	poire *pear*	pomme *apple*	22.5	5	5
cimpre	jardin *garden*	souris *mouse*	rat *rat*	21.3	6	3
lorme	école *school*	tigre *tiger*	lion *lion*	18	5	4
fondineau	cathédrale *cathedral*	fourchette *fork*	couteau *knife*	49.5	10	7
laupie	cachet *tablet*	moufle *mitten*	gant *glove*	43.8	6	4
tuscor	cousin *cousin*	chaise *chair*	table *table*	34.8	6	5
taurache	antilope *antelope*	ceinture *belt*	pantalon *pants*	34.8	8	8
luive	pompe *pump*	gomme *gum*	crayon *pencil*	30.3	5	6
vuirier	épingle *pin*	voilier *sailboat*	bateau *boat*	25.8	7	6
flocre	jambon *ham*	canapé *sofa*	lit *bed*	22.5	6	3
révaude	léopard *leopard*	commode *dresser*	armoire *cupboard*	19.1	7	7
Mean				32.2	6.27	5.67
		Category-related and weakly associated words				
bluime	cordon *cord*	fraise *strawberry*	framboise *raspberry*	7.8	6	9
gipane	ballon *balloon*	cochon *pig*	truie *sow*	5.6	6	5
lomeur	caméra *camera*	tulipe *tulip*	rose *rose*	5.6	6	4
boumin	voisin *neighbour*	mouton *sheep*	agneau *lamb*	4.5	6	6
fisangre	ménagère *housewife*	pastèque *watermelon*	melon *melon*	4.5	8	5
chaube	soldat *soldier*	chèvre *goat*	brebis *ewe*	3.3	6	6
cébol	génie *spirit*	aigle *eagle*	vautour *vulture*	3.3	5	7
cemprisse	catalogue *catalogue*	tournevis *screwdriver*	marteau *hammer*	9	9	7
blou	nerf *nerve*	jupe *skirt*	robe *dress*	7.8	4	4
cedotar	boucher *butcher*	manteau *coat*	veste *jacket*	7.8	7	5
pailone	meunier *miller*	chemise *shirt*	cravate *tie*	7.8	7	7
chonfre	médecin *doctor*	chapeau *hat*	casquette *cap*	4.5	7	9
ragoge	menton *chin*	valise *suitcase*	sac *bag*	4.5	6	3
handeur	mouette *gull*	collier *necklace*	bracelet *bracelet*	3.3	7	8
soube	patin *skate*	tasse *cup*	assiette *plate*	2.2	5	8
Mean				5.43	6.33	6.2

(*continued*)

APPENDIX 1
(*Continued*)

Primes			*Target words*			
Neutral	*Unrelated*	*Related*		*AS*	*LNP*	*LNT*
		Function-related and strongly associated words				
chune	hotte *hood*	ruche *hive*	abeille *bee*	82	5	7
fef	fée *fairy*	nid *nest*	oiseau *bird*	75.3	3	6
tiloure	clôture *enclosure*	berceau *cradle*	bébé *baby*	68.5	7	4
berorqueur	calendrier *calendar*	balançoire *swing*	enfant *child*	29.2	10	6
seple	bulle *bubble*	bague *ring*	doigt *finger*	27	5	5
vibière	drapeau *flag*	carotte *carrot*	lapin *rabbit*	23.6	7	5
rupois	verrou *bolt*	banane *banana*	singe *monkey*	14.6	6	5
lirmate	biberon *baby's bottle*	serrure *lock*	clé *key*	70.7	7	3
clupard	moineau *sparrow*	pinceau *brush*	peinture *paint*	63	7	8
teipre	équipe *team*	flèche *arrow*	arc *arc*	52.8	6	3
flilotte	trombone *trombone*	cendrier *ashtray*	cigarette *cigarette*	43.8	8	9
norpet	beurre *butter*	cloche *bell*	église *church*	37.1	6	6
pûlte	vigne *vine*	évier *sink*	vaisselle *dishes*	32.6	5	9
faimon	disque *disc*	casque *helmet*	moto *motorbike*	31.5	6	4
gine	juge *judge*	rame *oar*	barque *small boat*	24.7	4	6
Mean				45.09	6.13	5.73
		Function-related and weakly associated words				
laivon	baquet *bucket*	cahier *notebook*	écolier *shoolboy*	9	6	7
dorpe	marin *sailor*	balai *broom*	sorcière *witch*	4.5	5	8
doreau	radeau *raft*	camion *truck*	pompiers *firemen*	4.5	6	8
méchoine	vignette *vignette*	barrière *barrier*	cheval *horse*	3.3	8	6
xube	anse *handle*	pipe *pipe*	homme *man*	2.2	4	5
rivoche	pochette *pouch*	aquarium *aquarium*	dauphin *dolphin*	2.2	8	7
tinien	croûte *crust*	laitue *lettuce*	limace *slug*	2.2	6	6
gniclutant	chaussette *sock*	citrouille *pumpkin*	carrosse *coach*	3.3	10	8
neurou	pyjama *pajamas*	ciseaux *scissors*	papier *paper*	6.7	6	6
nifêtre	gorille *gorilla*	cadenas *padlock*	vélo *bike*	6.7	7	4
vongerail	marguerite *daisy*	astronaute *astronaut*	fusée *rocket*	4.5	10	5
natovol	branche *branch*	voiture *car*	route *road*	4.5	7	5
vrale	barbe *beard*	tente *tent*	piquets *stakes*	3.3	5	7
bérot	guêpe *wasp*	canon *canon*	poudre *powder*	3.3	5	6
carchatier	sauterelle *grasshopper*	aspirateur *vacuum*	moquette *carpet*	3.3	10	8
Mean				4.23	6.87	6.4

Notes: AS: association strength for related words; LNP: letter number for primes; LNT: letter number for targets.

APPENDIX 2

Standard deviations in analyses of variance for lexical decision latencies (errors) in skilled and less-skilled comprehenders at a long SOA (800 ms) according to relation type, association strength, and priming context

Relation Type × Association Strength	*Priming Context*					
	Skilled comprehenders			*Less-skilled comprehenders*		
	Neutral	*Unrelated*	*Related*	*Neutral*	*Unrelated*	*Related*
Categorical–Strong	292 (7.7)	246 (10.3)	238 (4.7)	163 (9.4)	260 (11)	215 (4.7)
Categorical–Weak	207 (8.6)	175 (7.7)	152 (7.7)	230 (10.3)	264 (12.2)	262 (6.5)
Functional–Strong	195 (7.7)	188 (9.2)	276 (6.5)	251 (7.7)	241 (6.5)	182 (4.7)
Functional–Weak	259 (11.9)	271 (8.6)	233 (4.7)	265 (9.2)	336 (14.1)	234 (0)