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# *The Fate of Global Precedence With Age*

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*The literature is virtually devoid of studies examining the effect of aging on the "global precedence" effect (Navon, D. [1977].* Cognitive Psychology, 9, *353–383). In this paradigm, global letters formed with local letters are shown, and the subject has to recognize either the local or the global letters. The relation between the global and the local letters is either congruent, neutral, or conflicting. Five experiments are reported, with five sets of 16 young and five sets of 16 elderly, healthy, adult subjects. The global precedence effect was observed in both age groups in the basic perceptual experiment as designed by Navon (Experiment 1). In addition, young and elderly subjects were able to process separately the global and the local shapes when attention was not directed towards a specific level (Experiment 1a). However, subpopulations emerged, especially in the elderly, depending on their ability to "resist" to the interference of the global shape upon the processing of the local form. This could support the few indirect published data suggesting that global precedence tends to diminish or to disappear with age. In experiments 2 and 2a, subjects were retained only if they did process the local level better than at random. Global precedence was confirmed in both young and elderly subjects. Again, elderly subjects manifested an increased sensitivity to interference. Moreover, a general effect of age remained, even in the control (neutral) conditions, suggesting difficulties of encoding in elderly. Therefore, in Experiment 3, encoding conditions of both age groups were equated by increasing exposure duration of the*

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*material for elderly. Subjects of Experiment 3 were also submitted to a Stroop test, to verify whether the increased sensitivity to interference in the elderly was specific to the "Navon task" or the expression of a general effect of aging on inhibition mechanisms. The global precedence phenomenon was observed in young and elderly subjects, with no sign of an effect of age under these conditions; in elderly, furthermore, the interference effect did not appear to result from a general aspecific deficit of inhibition mechanisms. It thus appears that the global precedence phenomenon resists well the effects of aging, but that subpopulations of elderly subjects should be considered in future studies.*

The phenomenon of global precedence in the visual perception of complex stimuli has been hypothesized since the beginning of the 20th century, and has been firmly demonstrated by Navon (1977). Surprisingly enough, in spite of the considerable amount of experiments which have since replicated the phenomenon under several methodological variations, very little is known about the effect of normal aging on global prevalence. The purpose of the present series of experiments was to fill this gap in the literature.

## GLOBAL PRECEDENCE

Studies in experimental psychology have shown, for a long time, that the visual perception of parts or local elements of a whole is influenced by the perception of the whole, which indicates that the whole is "more than the sum of the parts" and that the part could even be the perceptual by-product of the whole. This kind of context effect was clearly established by the Gestaltists between the two World Wars, as well as more recently (e.g., Palmer, 1980; Palmer & Bucher, 1981). Some current well-known effects can also be conceived within this framework: the word superiority effect (Estes, 1975; Reicher, 1969), the object superiority effect (Weisstein & Harris, 1974), and the face superiority effect (Davidoff & Donnelly, 1990; Thompson, 1980; Valentine & Bruce, 1985; Young, Hellawell, & Hay, 1987). However, in these studies, the global form (the "whole") differs structurally from the local component elements (the "parts"); for example, small triangles (part) forming a line (whole), letters composing a word, an eye within a face, or tub in a bathroom. Therefore, the so-called "superiority," "primacy," "priority," "prevalence," or "precedence" of the whole over the parts could result from structural (complexity) and/or familiarity differences, facilitating the discrimination or identification of the whole over the discrimination or identification of the parts.

In a seminal publication, Navon (1977) solved this uncertainty by designing particular "compound (or hierarchical) stimuli" where similar shapes (except for their size, of course) formed both the local and the global levels. Thus, Navon (1977) displayed briefly upper-case printed letters formed with smaller upper-case letters. For a given large letter, all the small component letters were identical, and they were either identical or not to the large one. A directed-attention paradigm was used. In one condition, the subjects (young adults) had to identify the large letter ; in the other condition, the small component letters. The global identification (large letters) was faster than the local one (small letters) and was unaffected by the conflicting condition (i.e., when the small component letters differed from the large), whereas the identification of the small letters slowed down when they differed from the large. This pattern of results was considered to be a demonstration of the "global precedence" phenomenon, that is to say, the perception of a complex pattern would proceed from global to local analysis. This effect could result from an early advantage of the processing of low resolution (low spatial frequencies) information (Hughes, Nozawa, & Kitterle, 1996).

This original study gave rise to many publications, including replications, generalization to other kinds of stimuli (nonverbal material, digits), populations (infants, children, brain-damaged subjects), and tasks (lateral visual hemifield presentation, copy drawing, memory recognition, and recall), and triggered debates about the conditions (number, size, sparsity, and "goodness" of the stimuli) in which the effect is and is not observed. The major part of this literature has been reviewed by Kimchi (1992) and will not be summarized here, except for the two specific fields that follow.

## NEUROPSYCHOLOGICAL DISSOCIATIONS

Neuropsychological investigations using the procedure designed by Navon (1977) not only support the global prevalence phenomenon but, in addition, suggest that different mechanisms underlie the processing of the global level and the processing of the local level.

First, divided–visual field behavioral studies in normal subjects seem to indicate that local parts of a compound stimulus are better processed by the left (right visual hemifield) than by the right cerebral hemisphere, whereas the global form is better processed by the right hemisphere (e.g., Hübner, 1998 ; Martin, 1979 ; Sergent, 1982). These designs and results have been used to assess hypotheses about schizophrenia (Ferman, Primeau, Delis, & Jampala, 1999 ; Granholm, Perry, Filoteo, & Braff, 1999). However, the picture is not completely clear for normal subjects. For instance, Boles and Karner (1996) and Van Kleeck (1989) point to the discrepancy of results between (and within) studies of hemifield presentation in normal subjects and clinical studies in unilaterally brain-injured subjects (see below).

Moreover, investigations of normal subjects by means of contemporary brain imagery techniques begin to contribute to the understanding of mechanisms underlying global and local processing, respectively. Thus, Han, Fan, Chen, & Zhuo (1997) recorded the event-related brain potentials during this kind of task and supported the view that the global precedence phenomenon takes place at early perceptual processing stages (see also Ridderinkhof & Van der Molen, 1995). Let us also note the studies by Fink and coworkers (1996, 1997a, 1997b, 1999) assessing, in normal subjects, the differential hemispheric contributions to local (left) and global (right) processing by means of the positron emission tomography procedure (see also Martinez, Moses, Frank, Buxton, Wong, & Stiles, 1997, for a study using the functional magnetic resonance procedure). We finally note that this global precedence could not be a universal property, as Fagot and Deruelle (1997) brought to light the global advantage, with interference of the global over the local level, in humans but a local advantage and no interference in baboons, by using the same procedure for both species.

Second, the differential effects of some diffuse or subcortical brain pathologies on local and global processing of compound stimuli have been investigated in group studies as well as in single-case reports. Filoteo et al. (1992) submitted normals and Alzheimer's disease patients to an experiment involving digits as stimuli under two attentional conditions: directed (to process either the global or the local level ; the procedure used by Navon, 1997) and divided attention tasks (to process both levels at each trial). Patients were slower than normals in both tasks, but particularly in the divided attention task, and this was mainly due to their inability to disengage and shift their attention (Posner, Walker, Friedrich & Rafal, 1984) from one level to the other. A similar pattern, but with qualitative differences, was found in parkinsonian patients by Filoteo et al. (1994). Filoteo et al. (1995) compared cortical (Alzheimer patients) and subcortical dementias (huntingtonian and parkinsonian patients) and found an impaired performance in the three samples (as compared to control subjects) that was due to different patterns: the shifting of attention was normal in huntingtonian patients, whereas parkinsonian patients were mostly impaired in maintaining visual attention, and Alzheimer patients were mainly impaired in the disengagement of attention. Finally, Delis et al. (1992) suggested two distinct subtypes, "high verbal" and "high spatial," of Alzheimer's disease patients on the basis of independent tests and it appeared that "high verbal" patients were particularly impaired in processing the local elements whereas "high spatial" ones were particularly impaired in processing the global shapes.

With regard to single-case studies of Alzheimer patients, one should note a study by Coslett, Stark, Rajaram, and Saffran (1995) that showed that two subjects processed faster the local rather than the global level (a pattern that documented the hypothesized restriction of their spotlight of visual attention). According to Coslett et al. (1995), the patient with semantic dementia described by Breedin, Saffran, and Coslett (1994) was also faster in processing the local rather than the global level. Let us note, however, that these subjects had been enrolled in a distributed attention condition, that the exposure duration was unlimited (up to the response), and that the target was verbally defined at each trial.

Third, experimental studies of groups of patients with a unilateral focal lesion deserve mention. In general, a defect in processing local parts of hierarchical stimuli is observed in groups of left-injured patients, whereas a defect in processing global elements is evidenced when right-damaged subjects are considered (Delis, Robertson, & Efron, 1986; Lamb, Robertson, & Knight, 1989, 1990; Robertson, Lamb, & Knight, 1988).

Fourth and finally, single-case studies of patients with a unilateral focal lesion must be mentioned. Polster and Rapcsak (1994) described two subjects suffering of a left hemisphere lesion and evidencing a precedence of the local over the global level in processing compound stimuli. More importantly, two independent studies revealed a double dissociation between the two levels. On the one hand, Marshall and Halligan (1995) described a patient with (left) hemineglect who processed normally global forms but neglected local forms in the left side of pictures. On the other hand, Doricchi and Incoccia (1998) described another patient with (left) hemineglect who neglected global forms of the left side and evidenced a general local precedence (on both sides of the material).

In conclusion, the contribution of neuropsychological studies is interesting and twofold. First, neuropsychology confirms that one level—the global one—receives priority over the other—the local one—and that this priority can be disrupted or reversed by brain damage. Second and more importantly, both levels can be completely dissociated. Indeed, each level can be disrupted by pathology while the other is spared, and, moreover, each level seems to depend on distinct cognitive mechanisms and/or cerebral structures. The study of normal aging could, in turn, contribute to document such a dissociation.

## EFFECTS OF AGING

Given these lessons offered by neuropsychological studies, a developmental approach could indeed be fruitful, by showing the evolution of the relationship between the global and local processes over the lifespan. Such a dynamic view will, hopefully, detect subtle mechanisms underlying these processes and a possible differential fate of global and local

**TABLE 1** Control Groups of Some Neuropsychological Studies

| Studies | Sample (*n*) | Mean age | Advantage | Precedence |
|---|---|---|---|---|
| Polster & Rapczak, 1994 | 5 | College students | Global | Global |
| Filoteo et al., 1995 | 15 | 49.3 | No | ? |
| Lamb et al., 1989 | 10 | 50 | Global | Global |
| Lamb et al., 1990 | 12 | 55 | Local | ? |
| Coslett et al., 1995 | 12 | 59.4 | Local | ? |
| Polster & Rapczak, 1994 | 5 | "In their 60s" | No | No |
| Filoteo et al., 1994 | 14 | 65.8 | No | ? |
| Filoteo et al., 1995 | 15 | 67.1 | No | ? |
| Delis et al., 1992 | 13 | 69.2 | Local | ? |
| Polster & Rapczak, 1994 | 5 | "In their 70s" | Local | Local |
| Filoteo et al., 1992 | 15 | 72 | No | No |

*Note*: Papers are ranked according to the age of the samples.

processing with normal aging. In other words, age can be another procedure that can document dissociations between the studied processes. Now, rather strangely, very few developmental studies employed compound stimuli with local and global shapes equal in complexity and familiarity. Therefore, it is worth noting that the global precedence phenomenon, as evidenced by means of hierarchical stimuli, is robust but, up to now, limited to the population of young adult subjects.

As a matter of fact, to our knowledge, the sole study examining the effects of age on the processing of hierarchic stimuli was carried out by Akshoomoff, Delis, and Haist (1993), who reported a detrimental age effect on the processing of local shapes. However, (a) this study used pairs of stimuli ; (b) stimuli were formed with letters, nameable shapes and non-nameable shapes ; and (c) the cognitive performance was approached by means of recall and recognition tasks.

Fortunately, other—but indirect—pieces of information can be found by examining the performance of control groups in some of the neuropsychological studies mentioned above. Table 1 summarizes the findings. Obviously, the global advantage and the global precedence usually observed in young adults vanish when older samples are considered. The study of Polster and Rapcsak (1994) is illustrative, even if each sample was formed with very few subjects: there appeared to be a global precedence in young subjects, no precedence in young-old subjects, and a local precedence in old subjects. The present study was planned to clarify this picture.

## THE PRESENT STUDY

The purpose of the present study was to explore the fate of the global precedence with age, by using a procedure very similar to that designed by Navon (1977 ; Experiment 3) and by comparing the performance of young to that of elderly adult subjects.

Given the lack of published studies assessing the effect of normal aging on this kind of task, a pragmatic goal of Experiment 1 was to check whether the "global precedence" effect would still be observed in elderly subjects. It is well known that aging effects are slight for many early, low-level perceptual processes (see Fozard, 1990, for a review), but the current literature shows that late, high-level visual processes are generally spared (see Bruyer, 1994, for a review). Therefore, elderly subjects of the present study were selected on the basis of a normal or corrected visual acuity, a short medical questionnaire (Christensen, Moye, Armson, & Kern, 1992 ; translated into French), and normal performance in a verbal evaluation of the intellectual level (the Mill-Hill vocabulary test, multiple-choice form ; French translation: Deltour, 1993). According to indirect observations summarized in Table 1, it was expected that global precedence aging will decrease to disappear with aging, or that a local precedence will appear.

## EXPERIMENT 1

### Methods

#### *Stimuli and Experimental Design*

The stimuli (upper-case printed letters, font Geneva, size 10 for local letters, plain) were drawn to be as similar as possible to those of Navon (1977). The material was displayed in black on a white background, on the screen of a microcomputer (Macintosh) whose luminosity and contrast were maximal. The size of the global letters was $25 \times 25$ mm, which corresponds to an angular size of $3.11 \times 3.11$ degree at the viewing distance of 50 cm. Global letters were composed of local letters. The shape of local letters was identical to that of the corresponding global letters and their size was 1/8 of that of the global letters. All local letters forming a given global letter were identical.

The eight stimuli were: a global H composed of local Hs, Ss, or Os (in short: HH, HS, HO) ;a global S also made up of local Hs, Ss, or Os (SH, SS, SO), and a global O composed of local Hs or Ss (OH, OS). "O" was used in the neutral conditions, and the task was to decide whether the target letter "H" or "S" was displayed.

In the *global task*, the subject had to make a decision about the global shape. In the *local task*, the decision concerned the local shapes. Each task included three conditions: *the consistent condition* involved stimuli in which letter identity was identical at both levels (HH and SS), the *conflictual condition* involved stimuli in which the identity of the global letter conflicted with that of the local letters (HS and SH), and *the neutral condition* involved the letter "O" at the to-be-ignored level (i.e., OH and OS in the local task and HO and SO in the global task).

Each task comprised 144 trials, randomly displayed. There were 48 trials for each condition (24 occurrences of each of the two available stimuli; e.g., 24 HH—24 SS = 48 consistent trials). The stimulus appeared randomly in one of the four quadrants around the fixation point (each localization was equally used) and was centered 2.6 cm (3.24 degree) away from the fixation point (a small cross $4 \times 4$ mm). Each stimulus was followed by a mask, a matrix of $32 \times 32$ dots, displayed in the same quadrant.

The 144 trials were grouped in four blocks of 36 trials. In each task, the analysis took into consideration only the last three blocks (108 trials, i.e., 36 per kind of trial); the first block served as a practice run and was not analyzed.

### Procedure

Each trial consisted of the following sequence of events: warning signal for 1 s, display of the fixation cross for 500 ms, display of the stimulus during 50 ms, immediate display of the mask until the response was given. The intertrial interval was 3 s. The subject produced the response by depressing one of two buttons on the keyboard (the two central keys above the space bar) by using the left or right index finger. One button was labelled "H" and the other "S."

### Subjects

Thirty-two subjects with normal or corrected visual acuity were recruited. The sample of *young subjects* comprised 16 participants (students recruited for credit courses), 8 females and 8 males. Their mean age was 19.25 years (range: 18–21). Their mean score in the Mill-Hill vocabulary test was 24.19 out of 34 (range: 12–30). The sample of *elderly subjects* was formed with 16 participants, 8 females and 8 males. Their mean age was 68.69 years (range: 65–74). Their mean score in the Mill-Hill vocabulary test was 31.12 out of 34 (range: 28–34), better than that of young subjects ($t(30) = 5.99$, $p < .0001$). These elderly subjects were retired but still active in several sociocultural associations and were members of the Third Age University. Each subject filled in a questionnaire concerning her/his medical history (Christensen et al., 1992; translated into French), and no subject failed any of the criteria of this medical screening.

Within each age group, four males and four females were submitted to the global task before the local task and the inverse sequence was used for the remaining four females and four males. Within these subsamples of four subjects, two subjects responded "H" with the left key and "S" with the right key, and the inverse applied to the remaining two subjects. For a given subject, the same assignment of keys applied to both tasks.

## Results

Table 2 shows the mean number of errors (out of 36: mean of the last three blocks) and the mean latency of correct responses for each sample, condition, and task.

### *Accuracy*

The number of errors was analyzed by means of an Age × Task × Condition analysis of variance (ANOVA) with two within-subject and one between-subject factors. All effects proved to be significant. Thus, significant main effects of age ($F(1, 30) = 9.16$, $p < .005$), of task ($F(1, 30) = 32.47$, $p < .0001$), and of condition ($F(2, 60) = 48.00$, $p < .0001$) emerged. These effects were qualified by significant Task × Age ($F(1, 30) = 7.52$, $p < .01$), Condition × Age ($F(2, 60) = 17.68$, $p < .0001$), and Task × Condition interactions ($F(2, 60) = 34.32$, $p < .0001$). Finally, the Age × Task × Condition interaction was also significant ($F(2, 60) = 14.10$, $p < .0001$). In order to explore these effects, a Task- × Condition ANOVA was computed on each age group separately.

For young subjects, a significant main effect of condition emerged ($F(2, 30) = 6.76$, $p < .004$ ;more errors appeared in the conflictual than in the remaining two conditions, but the latter two conditions did not differ from each other). The condition main effect interacted with task, as indicated by the significant Task × Condition interaction ($F(2, 30) = 6.22$,

**TABLE 2** Results of Experiment 1: Mean Number of Errors (Out of 36) and Mean Latency of the Correct Responses (ms) as a Function of the Age Group, the Task, and the Condition

| | Task | | | | | |
|---|---|---|---|---|---|---|
| | Global | | | Local | | |
| Condition | Consistent | Neutral | Conflictual | Consistent | Neutral | Conflictual |
| Young | | | | | | |
| Errors (/36) | 0.67 | 0.44 | 1.00 | 1.63 | 2.94 | 5.31 |
| Latency (ms) | 578 | 582 | 608 | 679 | 693 | 831 |
| Elderly | | | | | | |
| Errors (/36) | 0.56 | 0.88 | 1.56 | 2.06 | 5.75 | 17.31 |
| Latency (ms) | 599 | 559 | 593 | 834 | 919 | 986 |

$p < .005$). The post hoc analysis of this interaction ($p \leq .05$) showed that the condition effect was due only to the local task where the number of errors was greater in the conflictual condition than in the remaining two (which did not differ from each other); in addition, there was an advantage of the global over the local task in the conflictual and neutral conditions.

For elderly subjects, the ANOVA disclosed a significant task main effect ($F(1, 15) = 49.41$, $p < .0001$) and a significant condition main effect ($F(2, 30) = 42.69$, $p < .0001$), favoring the consistent over the neutral and the conflictual conditions (which did not differ from each other). However, both main effects were qualified by the significant Task $\times$ Condition interaction ($F(2, 30) = 28.43$, $p < .0001$). The post hoc analysis of this interaction showed that the task effect was due to the neutral and the conflictual conditions (no task effect for the consistent condition), and that the condition effect was due to the local task only, where advantages of the consistent over the neutral, and of the neutral over the conflictual condition, appeared.

Finally, given the significant triple order interaction observed in the main analysis, age effects were studied by means of separate $t$ tests computed for each condition of each task. Only one of the six tests proved to be significant. Namely, in the conflictual condition of the local task, the number of errors was significantly greater in elderly than in young subjects ($t(30) = 4.13$, $p < .0003$).

### *Latency of Correct Responses*

The Age $\times$ Task $\times$ Condition ANOVA evidenced significant main effects of task ($F(1, 30) = 18.62$, $p < .0002$) and of condition ($F(2, 60) = 9.67$, $p < .0002$). However, both main effects were qualified by the significant Task $\times$ Condition interaction ($F(2, 60) = 8.33$, $p < .0006$). No other effect was significant. In particular, age had no effect on correct latency, either as a main effect or as an interaction.

The post hoc analysis of the interaction showed no significant effect of the condition in the global task. In the local task, the conflictual condition differed significantly from the central ($p < .0001$) and the consistent conditions ($p < .0001$); in addition, the neutral condition differed from the consistent one in the local task ($p < .046$). The task effect was significant for each condition (all $p$ values $< .0001$).

## Discussion

The "global precedence" phenomenon (Navon, 1977) was observed in young and elderly subjects for both dependent variables. In addition, the sole effect of age concerned the conflictual condition of the local task on accuracy. Finally, a facilitation effect of the consistent condition appeared in the local task, and accuracy in elderly and on correct latency in both samples. Thus, it appeared that aging has little effect on the global precedence effect.

However, the picture is a bit more complicated. Indeed, accuracy of elderly in the conflictual condition of the local task was very close to the random level (48.1% errors), which precludes the interpretation of correct latencies. As a matter of fact, this was due to a bimodal distribution of the sample. Indeed, by taking 45 and 63 errors out of 108, i.e., 15 and 21 errors (these values included) out of 36 per block, as limits of the random performance (as attested by chi-square tests) in the conflictual condition of the local task, it appeared that two elderly subjects fell within the random range (mean = 15); eight other subjects produced less than 15 errors in this condition (mean = 10.3), whereas the remaining six produced more than 21 errors (mean = 27.3). In addition, both subgroups produced few errors in the remaining two conditions (first subgroup: 4.25 for the neutral and 3.5 for the consistent condition; second subgroup: 6.4 for the neutral 0.83 for the consistent condition). It thus appeared that eight subjects clearly showed an interference effect but did not base their response on the global letter (which is further supported by their performance in the neutral condition), and that six other subjects revealed an obvious interference effect and did, in fact, base their response on the global letter (which was not possible in the neutral condition). Let us note that the two subgroups did not differ in age and in their Mill-Hill score, as confirmed by Student *t* tests. When young subjects were considered, we detected one subject performing at random (18 errors) and another subject performing worse than randomly in the conflictual condition of the local task (28 errors).

It thus seems that subpopulations underly the sample of elderly subjects with respect to this kind of task. At the individual level, the random performance in the conflictual condition of the local task was due to only 2 subjects, whereas the remaining 14 formed two distinct subsamples. First, like young subjects, the elderly were obviously sensitive to the interference from the global shape during the processing of the local one. Second, this interference arose from the identity of the global letter, not from the presence of a global shape only, as seen by the performance of the elderly in the neutral condition. Third, it seems, however, that there were several kinds of sensitivity to interference underlying the responses of the elderly. Indeed, 50% of the elderly performed like young subjects and displayed the usual pattern of interference, that is to say, a slowing down of correct responses and a "tolerable" (i.e., not random) number of errors. Another two subjects were totally unable to discriminate the two target letters in the local task, provided the global shape was a possible target too (indeed, their performance was not random in the neutral condition); in addition, they performed adequately in the consistent condition. Finally, about a third of the elderly subjects were so sensitive to interference that they responded to the global letter, even in the local task; consequently, a good performance appeared in the consistent condition and a biased performance in the conflictual condition. And yet, they were able to process the local shapes, even embedded in a global one, provided this global form was not a candidate letter (i.e., in the neutral condition). These subsamples of elderly did not differ from each other in age and in Mill-Hill score but, even if we have no other explanation to offer for this heterogeneity, it is in good agreement with the often reported increase in between-subject variability with age (see Rabbitt, 1993, for a review) as well as the trend toward a reduction of the global precedence phenomenon with age (Table 1).

However, caution is required because psychometric properties of the distribution are poorly known in this study. Experiment 2 was planned to clarify the matter by enrolling subjects performing better than at random in the conflictual condition of the local task.

Moreover, before a clear statement about precedence effect is possible, it is important to determine whether subjects are able to process both the global and local levels separately, i.e., that information is discriminable at the two levels when attention is not directed towards a particular level. For instance, the absence of interference of the local level in the processing of the global level (conflictual condition), as well as the absence of facilitation in the consistent condition (as compared with the neutral condition) of the global task could simply indicate that when attention is directed to the global level, the local elements are not detected. Experiment 4 of the seminal paper of Navon (1977) had also been designed to control this point. In short, one has to be certain that the prevalence of the global over the local level is a true perceptual phenomenon, and not related to decisional processes.

Experiment 1a was designed to test such a possibility and, hopefully, support and validate the pattern of precedence observed in Experiment 1. The stimuli of Experiment 1 were again used, in a same/different discrimination task with two stimuli shown simultaneously at each trial, in two quadrants of the display. The two stimuli were identical in half the trials, different at the global level in 25% of the trials, and different at the local level in the remaining 25%. We acknowledge that the contribution of Experiment 1a should be considered with caution because, for obvious practical reasons, it was submitted to different subjects than those of Experiment 1.

## Experiment 1a

The material was exactly the same as that of Experiment 1. Each subject was submitted to 240 trials randomly distributed in a single task. In each trial, two stimuli were simultaneously displayed, in two randomly selected (and equally used) quadrants and followed by a pair of masks.

A speeded same/different decision was required, by using the same keys as in Experiment 1. In 120 trials, the two stimuli were identical (15 times each pair of identical shapes). In 60 trials, the two stimuli differed only at the local level (pairs HH/HO, HH/HS, HO/HS, SH/SO, SH/SS, and SO/SS, 10 times each). In 60 trials, the two stimuli differed only at the global level (pairs HH/OH, HH/SH, OH/SH, HS/OS, HS/SS, and OS/SS, 10 times each). These 240 trials resulted from five continuous repetitions of a block of 48 trials. The analysis will only consider the last four blocks (192 trials, i.e., 96 same, 48 different at the global level, and 48 different at the local level). The first block served as a practice run. Each trial comprised the same events as in Experiment 1, with two simultaneous stimuli instead of one, a double mask, and a same/different kind of response. One button was labelled "same" and the other "different." Instructions did not direct attention to a particular level.

Thirty-two new subjects, selected in the same manner as those in Experiment 1, were enrolled. The mean age of the young subjects was 19.4 years (range: 18–24). Their mean score in the Mill-Hill vocabulary test was 26.44 out of 34 (range: 20–32). The mean age of elderly subjects was 68.9 years (range: 65–76). Their mean score in the Mill-Hill vocabulary test was 31.06 out of 34 (range: 27–33), again better than that of young subjects ($t(30) = 5.13$, $p < .0001$). Within each age group, four males and four females responded "same" with the left key and "different" with the right key, and the inverse assignment applied to the remaining subjects.

Given the purpose of this experiment, analyses were limited to different trials only. The *proportion of errors* was examined by an Age × Level (global vs. local) ANOVA. A significant main effect of age ($F(1, 30) = 8.06$, $p < .008$) was observed that favored young over elderly subjects (19.1 vs. 31.3%), as well as a significant effect of the level ($F(1, 30) = 91.01$, $p < .0001$), indicating that differences were better detected at the global than at the local level (3.4 vs. 46.9%). The interaction was not statistically contributive. For global differences, the number of errors differed from the random level in young ($t(15) = 106.79$, $p < .0001$) as well as in elderly subjects ($t(15) = 32.75$, $p < .0001$). For local differences, young subjects performed better than at random ($t(15) = 2.16$, $p < .048$), but elderly subjects did not ($t(15) = 1.15$, *NS*).

Obviously, the task was difficult, especially in the locally different condition, and even for young subjects. Actually, when thresholds of 18 and 30 errors out of 48 were defined as the limits of the random area (these values included, as attested by chi-square tests), only 9 out of the 16 young subjects performed better than at random (mean = 9.11 errors); 5 subjects performed randomly (mean = 24 errors), and another 2 performed worse than the random level (mean = 40 errors). Note that these three subsamples did not differ in age and in their score in the Mill-Hill test, as attested by nonparametric Kruskal-Wallis tests. The pattern was still more impressive for elderly subjects. As a matter of fact, their quasi-random performance in the "locally different" condition resulted from a subsample of subjects. Indeed, four subjects failed in the random area (mean number = 20.5) and nine subjects performed "worse" than the random level (mean = 36.3), so that only three subjects produced fewer errors than predicted by random decisions (mean = 10). These three subsamples did not differ in age and in their Mill-Hill score, as attested by Kruskal-Wallis tests.

For *correct latencies*, the Age × Level ANOVA revealed only a significant main effect of the level ($F(1, 30) = 62.14$, $p < .0001$), favoring the global over the local level (747 vs. 1114 ms).

Clearly, the global precedence effect observed in the young subjects of Experiment 1 cannot be explained by an inability to process the local level when the attention is not directed towards a particular level. However, we have to note that only 9 young subjects out of 16 were able to detect local differences better than at random, and that different subjects were enrolled in Experiments 1 and 1a. The picture is a bit more complex for elderly subjects. Indeed, only 3 elderly subjects out of 16 were able to detect local differences better than at random. Experiment 2a was planned to enroll subjects able to process the locally different pairs better than at random.

## Conclusion

As a group, young adult subjects performed very much like those of Navon (1977), evidencing the global prevalence phenomenon in Experiment 1, i.e., there was an advantage of the global over the local task, and of the neutral over the conflictual condition in the local task only. In addition, this phenomenon was not accounted for by a decision bias, as young subjects were able to process both the global and the local level when attention was not directed toward a particular level (Experiment 1a). However, it remains that different subjects were enrolled for the two experiments, and that a within-subject design should clarify this point. For elderly subjects, the pattern was more complex, as 50% of them performed better than at random in the conflictual condition of the local task (Experiment 1) and three subjects only in the locally different condition of the matching task (Experiment 1a).

One lesson of Experiments 1 and 1a is that subpopulations in the elderly have to be considered, even though they do not differ from each other in age or in verbal proficiency, when high-level perceptual processes are investigated. This point will be considered in Experiments 2 and 2a, where we attempted to constitute samples of 16 young and 16 elderly subjects performing better than at random in the local condition. It is worth noting that this procedure raises the important issue of generalizability of the findings with respect to understanding the aging process. However, this issue should not be overestimated. Indeed, after all, this kind of procedure is systematically used for sake of methodology. For instance, in the literature, groups of elderly subjects are generally selected as being equivalent to the control group of young adults with respect to, say, sociocultural level, crystallized intelligence, or visual efficiency.

In the local task (Experiment 1) or condition (Experiment 1a), accuracy was lower in elderly than in young subjects, so that a difference in the level of difficulty for processing the signal could have introduced biases in the study of latency. This point will be considered in Experiment 3, where accuracy of the elderly was improved by allowing them to process the signal more efficiently (by manipulating the stimulus duration and the stimulus-mask interval).

It was useful to carry out Experiments 1 and 1a, because the effect of aging on the global prevalence phenomenon, as evidenced by the Navon paradigm, has never been reported in the literature.

## EXPERIMENT 2

### Methods

Experiment 2 was identical to Experiment 1, but we enrolled subjects in such a way that 16 young and 16 elderly subjects were able to perform the conflictual condition of the local task better than at random. As a matter of fact, the data of the 14 young and 8 elderly "normal" subjects of Experiment 1 were again used, and we attempted to find 2 additional young "normal" subjects and 8 additional elderly "normal" subjects and submitted them to the corresponding hand and button conditions of the discarded subjects of Experiment 1. To do this, we were obliged to enrol only 2 young subjects, but 13 elderly subjects. The final set of young subjects was 19.44 years old (range: 18–23; mean Mill-Hill score = 24.12; range: 12–30) and the final set of elderly subjects was 69.37 years old (range: 6.5–78; mean Mill-Hill score = 31.12; range: 28–33). The elderly performed significantly better than the young subjects in the Mill-Hill test ($t(30) = 6.125, p < .0001$).

### Results

Table 3 shows the mean number of errors (out of 36: means of the last three blocks) and the mean latency of correct responses for each sample, condition, and task.

#### *Accuracy*

The Age × Task × Condition ANOVA evidenced significant main effects of task ($F(1, 30) = 33.39, p < .003$), condition ($F(2, 60) = 34.82$,

**TABLE 3** Results of Experiment 2: Mean Number of Errors (Out of 36) and Mean Latency of the Correct Responses (ms), as a Function of the Age Group, the Task, and the Condition

| | Task | | | | | |
|---|---|---|---|---|---|---|
| | Global | | | Local | | |
| Condition | Consistent | Neutral | Conflictual | Consistent | Neutral | Conflictual |
| Young | | | | | | |
| Errors (/36) | 0.50 | 0.39 | 1.28 | 1.11 | 1.33 | 3.72 |
| Latency (ms) | 565 | 566 | 599 | 754 | 759 | 878 |
| Elderly | | | | | | |
| Errors (/36) | 0.69 | 0.69 | 1.13 | 2.31 | 2.81 | 8.88 |
| Latency (ms) | 609 | 615 | 596 | 775 | 808 | 893 |

$p < .0001$), and age ($F(1, 30) = 10.92$, $p < .003$), as well as significant Task × Condition ($F(2, 60) = 27.79$, $p < .0001$), Age × Task ($F(1, 30) = 17.29$, $p < .0002$), and Age × Condition interactions ($F(2, 60) = 6.93$, $p < .002$). In addition, the Age × Task × Condition interaction was significant ($F(2, 60) = 11.87$, $p < .0001$). Post hoc comparisons showed a significant advantage of young over elderly subjects in each condition of the local task (consistent: $t(30) = 2.19$, $p < .04$; neutral: $t(30) = 2.52$, $p < .02$; conflictual: $t(30) = 4.75$, $p < .0001$), with no effect of age in the three conditions of the global task. The triple interaction was decomposed into two Task × Condition ANOVAs separately computed on each age group.

For young subjects, there was a trend towards an effect of the task ($F(1, 15) = 3.46$, $p < .083$). The main effect of condition was significant ($F(2, 30) = 5.14$, $p < .015$; more errors in the conflictual than in the remaining two conditions, not differing from each other), and the Task × Condition interaction just failed to reach the critical threshold ($F(2, 30) = 3.14$, $p < .058$). The post hoc analysis of this interaction ($p \leq .05$) showed that the number of errors was significantly higher in the conflictual condition of the local task than in the remaining five Task × Condition combinations (not differing from each other). So, the task effect was only due to the conflictual condition, and the condition effect appeared only in the local task.

For elderly, there was a significant effect of the task ($F(1, 15) = 30.46$, $p < .0001$). The main effect of condition was significant ($F(2, 30) = 37.99$, $p < .0001$; more errors occurred in the conflictual than in the remaining two conditions, which did not differ from each other), as was the Task × Condition interaction ($F(2, 30) = 26.05$, $p < .0001$). The post hoc analysis of this interaction ($p \leq .05$) showed that the number of errors was significantly higher in the conflictual condition of the local task than in the remaining five Task × Condition combinations, and higher in the neutral condition of the local task than in the neutral and consistent conditions of the global task. So, the task effect was due to the conflictual and neutral conditions, and the condition effect appeared in the local task only.

To explore more specifically a possible effect of age on the global precedence, a last post hoc ANOVA was computed on the neutral and conflictual conditions of the local task, with age and condition as factors. Significant main effects of age ($F(1, 30) = 20.43$, $p < .0001$) and condition ($F(1, 30) = 44.65$, $p < .0001$) were observed, as well as a significant Age × Condition interaction ($F(1, 30) = 13.00$, $p < .0015$), showing that the interference was higher in elderly than in young subjects (additional 6.06 vs. 1.81 errors).

### *Correct Latency*

The Age × Task × Condition ANOVA evidenced main effects of task ($F(1, 30) = 10.90$, $p < .0025$) and condition ($F(2, 60) = 7.94$, $p < .001$), as well as a significant Task × Condition interaction ($F(2, 60) = 8.13$, $p < .0009$). However, no trace of effect of age was detected, either as a main effect or in interactions. The Task × Condition significant interaction was analyzed further. It appeared a significant effect of the task for each condition (all $p$ values $< .0001$), no effect of the condition in the global task, and a significant difference between the conflictual and both other conditions (not differing from each other) in the local task (both $p$ values $< .0001$).

The post hoc Age × Condition ANOVA on the neutral and conflicting conditions of the local task verified the significant main condition effect ($F(1, 30) = 9.07$, $p < .006$), but failed to disclose a significant main age effect and a significant Age × Condition interaction (the cost induced by the conflictual condition was 131 ms in young subjects and 84 ms in elderly subjects, *NS*).

## Discussion

Young subjects displayed the classic “global precedence” phenomenon, a pattern observed with both dependent variables. The elderly, also, displayed this pattern in both measures. At first glance, when “good” performers are selected, no sign of an age effect was detectable in the results. However, we noted a detrimental effect of aging in the local task, in particular an increased sensitivity to interference (conflictual condition), and this effect was limited to accuracy. So, expectations were partially supported. However, because the effect of aging appeared in the three conditions of the local task (the increased interference emerged only from a very specific post hoc ANOVA), it could be that age effect is the result of a general increased difficulty of the local task. Experiment 3 was designed to solve this uncertainty.

However, before starting Experiment 3, we wanted to clarify the picture observed in Experiment 1a, by enrolling young and elderly subjects able to process the locally different pairs better than at random, in a task where attention is not directed to a particular level.

## Experiment 2a

Experiment 2a was similar to Experiment 1a, but we enrolled subjects in such a way that 16 young and 16 elderly subjects were able to process the locally different pairs better than at random. In addition, we recall that Experiment 1a was very difficult, because only three elderly and nine young subjects did reach this criterion of accuracy. This resulted from the perceptual conditions: subjects had to process two simultaneous stimuli at the two levels (global and local) under the same (and short: 50 ms) exposure duration as that of the single stimulus of Experiment 1 of which only one level had to be processed. In addition, preliminary attempts to select "good" performers failed (none of the five young and five elderly subjects enrolled were able to satisfy the criterion). Therefore, a methodological adaptation was provided, and submitted to new young and elderly subjects. Thus, Experiment 2a was a close adaptation of Experiment 1a, with 16 young and 16 elderly "normal" subjects in the locally different condition. To do this, and in spite of the methodological modification, we enrolled 19 young and 33 elderly subjects. The final set of 16 young subjects was 19.9 years old (mean Mill-Hill score = 26.69) and the final set of 16 elderly subjects was 70.6 years old (mean Mill-Hill score = 29.90 ; $t(30) = 2.87$, $p < .008$). The methodological adaptation was as follows. The two stimuli of each trial were displayed sequentially instead of simultaneously, with the first stimulus shown for 1 s and immediately followed by the second stimulus for 50 ms. Thus, the decision had to be taken on a single stimulus seen in the same conditions as in Experiments 1 and 2. Response latency was measured from the onset of the second stimulus. Once again, given the purpose of this experiment, analyses were limited to different trials only.

The *proportion of errors* was examined by an Age × Level ANOVA. The main age effect was significant ($F(1, 30) = 19.53$, $p < .0001$) as well as the main level effect ($F(1, 30) = 20.27$, $p < .0001$), but both effects were qualified by the significant interaction ($F(1, 30) = 5.00$, $p < .03$) which was analyzed in more depth. The effect of the level was significant in each age group (young: 1.8 vs. 7.2% errors ; $F(1, 15) = 10.09$, $p < .007$ ; elderly: 5.3 vs. 21.2%: $F(1, 15) = 13.01$, $p < .003$). Moreover, there appeared a significant advantage of young over elderly subjects for locally different trials ($F(1, 30) = 19.96$, $p < .0001$), but no effect of age for globally different trials ($F(1, 30) = 1.36$).

For *correct latencies*, the Age × Level ANOVA revealed a significant main age effect ($F(1, 30) = 5.54$, $p < .026$) as well as a significant main effect of the level ($F(1, 30) = 15.28$ ; $p < .0005$). In addition, both effects were qualified by the significant interaction ($F(1, 30) = 6.45$, $p < .02$). There appeared an advantage of young over elderly subjects for locally different trials (1014 vs. 1262 ms ; $F(1, 30) = 9.98$, $p < .004$) but not for globally different trials (978 vs. 1089 ms ; $F(1, 30) = 1.79$). For young subjects, there was no significant effect of the level ($F(1, 15) = 2.35$) ; for elderly subjects, correct responses were faster for globally different than for locally different trials ($F(1, 15) = 12.98$, $p < .003$).

So, in Experiment 2a, the accuracy and speed of correct responses were better in young than in elderly subjects. Moreover, this was mainly observed when stimuli differed at the local level. However, the main lesson of this experiment is that elderly (and, of course, young) subjects were able to process the local level even when their attention was distributed over both the global and the local levels.

## Conclusion

When young and elderly subjects were carefully selected on the basis of performing better than at random, we confirmed, in both age groups, the presence of the classical effects first reported by Navon (1977). These include a global precedence phenomenon (Experiment 2), which could not be attributed to a failure to process the local level when attention is shared on both levels (Experiment 2a). We also confirmed the well-known effect of aging on cognitive performance, especially when speed of response is considered, i.e., aging slows down cognitive operations.

It also appeared that elderly people seemed to be exaggeratedly sensitive to interference. Indeed, in the local task, the conflicting condition was particularly difficult for them and there were signs of facilitation in the consistent condition. In addition, the elderly also differed from young subjects in the neutral conditions, which might suggest some difficulties of encoding with aging resulting, perhaps, from the (short) exposure duration.

In order to explore in more depth this hypothesis, Experiment 3 was therefore planned. First, subjects were submitted to an independent interference test (the Stroop task, see below) to examine whether the increased sensitivity to interference in old age was specific to the "Navon task" or the manifestation of a more general phenomenon. Second, exposure duration of the stimuli was longer in elderly than in young subjects in an attempt to suppress age effects in the neutral condition in such a way that encoding problems could be ruled out in explaining age effects on the global precedence phenomenon.

## EXPERIMENT 3

As in Experiment 2, the subjects of Experiment 3 were selected only if they were able to perform the conflictual condition of the local task better than at random, namely, by producing less than 15 errors out of 36 trials. Experiment 3 was identical to Experiment 2, with two modifications. The first modification concerned the selection of elderly subjects, as they were retained only when their accuracy in the neutral condition of the local task (used as baseline) did not differ statistically from that of young subjects. The criterion was the mean —2.5 standard deviations of the accuracy of young subjects, i.e., as shown below, no more than 3 errors out of 36. Indeed, we wanted to compare young to elderly subjects after having equated the performance of both samples for this baseline condition, i.e., by neutralizing possible age effects in the encoding process (because age can affect basic sensory visual processes ; see Fozard, 1990, for a review). This was made by displaying the stimuli for 200 ms in the elderly (against 50 ms in the young), and by providing a blank interval of 50 ms between the offset of the stimulus and the onset of the mask in the elderly (against 0 ms in the young).

The second modification was the addition of an independent measure. Indeed, the elderly subjects of Experiments 1 and 2 seemed to have difficulties in inhibiting the "automatic" processing of the global shape when they had to process the local shape. Now, an aspecific deficit of inhibition is sometimes suggested as the basic mechanism of cognitive aging (e.g., Hasher, Stoltzufs, Zacks, & Rypma, 1991). To check whether or not this phenomenon was specific to the "Navon task," a Stroop test was added as a measure of inhibition. In the Stroop test (1935), the task requires subjects to name the color in which a word is written and to ignore the name (in fact, a color name). In such tasks, it is observed that reading is unavoidable ; in particular, reading times are slower when the word names a different color than the target, than when the word names a noncolor or the same color as the target. This "Stroop effect" has been abundantly studied and used in the literature (see MacLeod, 1991 for review).

### Method

We replicated Experiment 2, with (a) 16 young and 16 elderly new subjects, selected as above, whose performance was "normal" in the conflictual condition of the local task ; and (b) where the performance of elderly subjects did not differ from that of young subjects in the neutral condition of the local task (no more than the mean —2.5 standard deviation errors, out of 36, of young subjects). To do this, we enrolled 22 young and 19 elderly subjects. The final set of 16 young subjects was 19.7

years old (mean Mill-Hill score = 24.44), and the final set of 16 elderly subjects was 72.6 years old (mean Mill-Hill score = 31.37 ; $t(15) = 5.81$, $p < .0001$). Six of the young subjects were replaced due to technical bugs (problems with data saving, fits of coughing, etc.) but all the remaining 16 subjects performed better than at random (less than 15 errors out of 36) in the conflictual condition of the local task. As will be seen below, their mean performance in the neutral condition of the local task was 1.25 errors out of 36, SD = 1.065, so that the criterion to retain the data of elderly was 3 errors or less in that condition. Three of the elderly subjects were discarded due to misunderstanding instructions (one male subject), too many errors in the neutral condition of the local task (one male subject), or too many errors in the conflictual condition of the local task (one female subject).

Subjects were also submitted to the Stroop test. In this test, the participant had to name as fast as possible the color of the stimuli. Each trial consisted of four rows of six stimuli each, and the dependent variable was the mean time to name all colors of one trial (i.e., of 24 stimuli). In the control condition, stimuli were strings of "X" (three trials). In the interference condition, stimuli were color names not congruent with the color of the word (three trials). In each condition, the recorded measure was the mean time to name the color of the 24 stimuli.

In each subsample of both age groups, half the subjects were submitted to the Mill-Hill test before the experiment and to the Stroop test after the experiment, and the reverse applied to the remaining half.

## Results

Table 4 shows the mean number of errors (out of 36: means of the last three blocks) and the mean latency of correct responses for each sample, condition, and task.

### *Accuracy*

The Age × Task × Condition ANOVA computed on the number of errors revealed significant main effects of the task ($F(1, 30) = 21.00$, $p < .0001$) and of the condition ($F(2, 60) = 25.75$, $p < .0001$), as well as a significant Task × Condition interaction ($F(2, 60) = 11.76$, $p < .0001$). Post hoc analysis of this interaction showed a significant effect of the task in the neutral ($p < .04$) and conflictual conditions ($p < .0001$), but not in the consistent condition. In addition, there was a significant effect of the condition in the local task, with significant differences between the conflictual and the neutral condition ($p < .0001$) and between the conflictual and the consistent condition ($p < .0001$), but not between the neutral and the consistent condition.

However, not the slightest sign of an age effect emerged, either as a main effect or in interactions (all $F$ values $< 1$). Moreover, the post hoc

**TABLE 4** Results of Experiment 3: Mean Number of Errors (out of 36) and Mean Latency of the Correct Responses (ms) as a Function of the Age Group, the Task, and the Condition

| | Task | | | | | |
|---|---|---|---|---|---|---|
| | Global | | | Local | | |
| Condition | Consistent | Neutral | Conflictual | Consistent | Neutral | Conflictual |
| Young | | | | | | |
| Errors (/36) | 0.61 | 0.56 | 1.22 | 1.00 | 1.28 | 3.61 |
| Latency (ms) | 580 | 599 | 651 | 699 | 690 | 779 |
| Elderly | | | | | | |
| Errors (/36) | 0.25 | 0.38 | 0.94 | 0.63 | 1.13 | 3.25 |
| Latency (ms) | 635 | 644 | 675 | 673 | 678 | 781 |

ANOVA computed on the neutral and conflictual conditions of the local task, with age and condition as factors, showed a significant main effect of condition ($F(1, 30) = 19.76$, $p < .0001$). However, age was not significant ($F < 1$) nor was the Age × Condition interaction ($F < 1$).

By way of control, separate Task × Condition ANOVAs were computed for each age group, and the first analysis was largely confirmed, with slight qualifications. Thus, for young subjects, there were significant effects of the task ($F(1, 15) = 17.31$, $p < .0008$), of the condition ($F(2, 30) = 13.06$, $p < .0001$), and of the interaction ($F(2, 30) = 6.28$, $p < .006$). The effect of the task was significant for the conflictual condition only ($p < .0001$) ; there was no effect of the condition in the global task. In the local task, there was a significant effect of the condition, with significant differences between the conflictual and the neutral condition ($p < .0001$) and between the conflictual and the consistent condition ($p < .0001$), but not between the neutral and the consistent condition. For elderly, there were significant effects of the task ($F(1, 15) = 7.38$, $p < .016$), of the condition ($F(2, 30) = 12.79$, $p < .0001$), and of the interaction ($F(2, 30) = 5.50$, $p < .01$). Post hoc comparisons showed (a) no effect of the condition in the global task ; (b) in the local task, a higher number of errors in the conflictual condition than in the remaining two conditions ($p < .0001$) not differing from each other ; and (c) an effect of the task in the conflictual condition only ($p < .0001$).

### *Latency of Correct Responses*

The Age × Task × Condition ANOVA evidenced main effects of task ($F(1, 30) = 16.62$, $p < .0003$) and condition ($F(2, 60) = 23.14$, $p < .0001$), as well as a quasi-significant Task × Condition interaction ($F(2, 60) = 3.07$, $p < .054$). There was a significant effect of task in each condition (consistent: $p < .0001$; neutral: $p < .0003$; conflictual: $p < .0001$). In the global task, the conflictual condition differed significantly from the consistent ($p < .002$) and the neutral conditions ($p < .02$), not differing from each other. In the local task, the conflictual condition differed significantly from the consistent ($p < .0001$) and the neutral conditions ($p < .0001$), not differing from each other.

However, no trace of an age effect was detected, either as a main effect ($F < 1$) or as an interaction (Age × Task: $F(1, 30) = 1.96$, *NS*; Age × Condition: $F < 1$; Age × Task × Condition: $F < 1$). The post hoc Age × Condition ANOVA on the neutral and conflicting conditions of the local task confirmed the significant main condition effect ($F(1, 30) = 28.81$, $p < .0001$), but failed to show a significant main age effect ($F < 1$) and a significant Age × Condition interaction ($F < 1$).

By way of control, separate Task × Condition ANOVAs were computed for each age group, and the first analysis was largely confirmed, but with slight qualifications. Thus, for young subjects, there were significant effects of the task ($F(1, 15) = 12.83$, $p < .003$) and of the condition ($F(2, 30) = 13.21$, $p < .0001$). The interaction was not significant ($F < 1$). However, as in Experiment 2, the cost induced by the conflictual condition showed that the interference of the global over the local level was greater than the interference of the local over the global level (96 vs. 53 ms). In addition, the pattern of errors convinced us that the global precedence phenomenon was at work. For elderly, a trend towards a main task effect ($F(1, 15) = 4.31$, $p < .056$) appeared, as well as a significant main effect of the condition ($F(2, 30) = 10.08$, $p < .0004$). The Task × Condition interaction was not significant ($F(2, 30) = 2.40$). However, the cost induced by the conflictual condition showed that the interference of the global over the local level was greater than the interference of the local over the global level (103 vs. 31 ms). In addition, the pattern of errors convinced us that the global precedence phenomenon was at work.

### Stroop Interference

Stroop interference was observed in young subjects, with mean color naming times of 15.33 s in the control condition and 20.46 s in the interference condition ($t(15) = 9.29$, $p < .0001$). No significant correlation emerged between the Stroop interference ([interference control]/[interference —control]) and the interference of the global level over the processing of the local level ($r = .212$) or the interference of the local level over the processing of the global level ($r = .286$) when correct latencies were considered. For errors, the correlation between the Stroop interference and the interference of the local level over the processing of the global level was marginally significant ($r = .465$, $df = 14$, $p < .05$), but the correlation between the Stroop interference and the interference of the global level over the processing of the local level was not ($r = .035$).

Stroop interference was also observed in elderly, with mean color naming times of 17.96 s in the control condition and 26.79 s in the interference condition ($t(15) = 12.09$, $p < .0001$). No significant correlation emerged between the Stroop interference ([interference control]/[interference —control]) and the interference of the global level over the processing of the local level ($r =$ .211) when correct latencies were considered ;a significant, but slight, correlation appeared between the Stroop interference and the interference of the local level over the processing of the global level ($r = .463$, $df = 14$, $p < .05$). For errors, the correlation between the Stroop interference and the interference of the local level over the processing of the global level was not significant ($r = .251$), and the same applied to the correlation between the Stroop interference and the interference of the global level over the processing of the local level ($r =$ .048).

The index of the Stroop interference was significantly higher in elderly (19.97%) than in young subjects (13.34%: $t(30) = 3.004$, $p < .0055$). Accordingly, the Age × Condition ANOVA computed on the scores in both conditions of the Stroop test evidenced a significant interaction ($F(1, 30) = 16.39$, $p < .0003$): the effect of conditions has already been reported in both age groups, and the effect of age was marginal in the control condition ($t(30) = 1.95$, $p < .06$), but robustly significant in the interference condition ($t(30) = 3.55$, $p < .0015$). Obviously, the main effects of age ($F(1, 30) = 8.72$, $p < .006$) and of condition ($F(1, 30) = 232.51$, $p < .0001$) were statistically significant.

## Discussion

In Experiment 3, perceptual encoding of the material was made as easy for the elderly as for the young subjects, by increasing exposure duration and defining a criterion of accuracy in the neutral condition of the local task. Under these conditions, the results were clear. First, for young subjects, the "global precedence" phenomenon was verified, no speed-accuracy trade-off was at work, and the precedence effect was unrelated to the interference effect as measured by means of the Stroop test. In addition, the (unexpected) interference of the local level on the processing of the global level when correct latencies were considered was explainable in part by a general sensitivity to interference, as testified by the correlation with the Stroop interference. Second, the global precedence phenomenon was observed in the elderly and no speed-accuracy trade-off appeared. Third, an important Stroop effect was observed in the elderly, but this index of interference was unrelated to the global precedence effect. Fourth, all signs of an effect of age as noted in the main experiment disappeared, even if the Stroop effect was greater in elderly than in young subjects.

Therefore, it appears likely that the effects of age on the global precedence observed in Experiments 1a and 2a were entirely due to difficulties of encoding the material, which probably results from slight sensory decline due to ageing (Fozard, 1990) ;in particular, it is worth noting that the increased sensitivity to interference noted in Experiments 1 and 2 was no longer observed when encoding was made easier (Experiment 3). Moreover, elderly subjects displayed an increased sensitivity to interference in the Stroop task, but their sensitivity to the global shape in the local task of the experiment was not the result of a general and nonspecific deficit of inhibition (Hasher et al., 1991), as attested to by the correlational analyses. In addition, as shown by a recent meta-analysis (Verhaegen & De Meersman, 1998), the effect of age on the Stroop effect could be an artifact resulting from the general slowing due to age ; this encourages the design of additional experiments, even if this point is marginal with respect to the purpose the present study.

## GENERAL DISCUSSION

Since the seminal publication of Navon (1977), the so called "global precedence effect" in the visual processing of compound stimuli under directed attention (i.e., global vs. local task) is characterized by: (a) an interference of the global level over the processing of the local level (conflictual condition as compared to neutral condition), together with, (b) no reciprocal and symmetric interference of the local level over the processing of the global level. Two additional, not mandatory features can be: (a) a processing advantage of the global over the local task, and (b) a facilitation effect in the consistent condition of the local task (as compared to the neutral condition). This global precedence effect is generally observed when analyzing the speed of correct responses, and it is robust, even if it can be modulated by many variables (see Kimchi, 1992, for a review).

The present study was designed to fill a gap in the current literature, namely, an investigation of the fate of the global precedence effect with aging. A series of three main experiments and two control experiments is reported, in which healthy elderly subjects were compared to young adults. Two dependent variables were studied, accuracy and correct latencies.

First, we summarize the main findings. *Experiment 1* was a close replication of the original experiment (Navon, 1977). In young subjects, the expected effects were exactly replicated for both accuracy and latencies. In the elderly, the effect was observed in accuracy only and took the form of an "exacerbation," as testified by the emergence of a facilitation effect in the consistent condition of the local task, and by the observation that about one third of the subjects, in the conflictual condition, actually processed the global shape in the local task. This supports the trend observed from indirect data (see Table 1), that suggests global precedence is reduced with age, or is even replaced by a local advantage phenomenon. Moreover, there was an advantage of young over "normal" elderly subjects only in the conflictual condition, and for accuracy only. *Experiment 1a* was a control discrimination task designed to check whether subjects were able to process the global and local levels together when attention was not directed towards a specified level. Young subjects were clearly able to perform such an operation. The picture was a bit more complex in the elderly, as about one half of them displayed difficulties in processing the local level (whereas the remaining half did not differ from young subjects). These difficulties resulted mainly from a high rate of false alarms, a pattern often associated with aging (e.g., Bartlett & Fulton, 1991 ; Bartlett, Strater, & Fulton, 1991 ; Fulton & Bartlett, 1991).

Given this state of affairs, *Experiments 2* and *2a* were planned. They were designed exactly as Experiments 1 and 1a, but subjects were selected only if they performed better than at random in the processing of the local level (conflictual condition, in Experiment 2). In agreement with what was observed in Experiments 1 and 1a, no young subject, but about 50% of elderly, were eliminated from Experiment 2 ; for Experiment 2a, a small number of young subjects ($n = 3$), but a substantial number of elderly subjects ($n = 17$), were eliminated, whereas the experiment had been made slightly easier than Experiment 1a. The young and elderly remaining subjects of Experiment 2 displayed the global precedence phenomenon and elderly subjects evidenced an increased sensitivity to interference of the global level over the processing of the local level. The young and elderly remaining subjects of Experiment 2a showed their ability to process both the global and the local levels when attention was not directed toward a predefined level.

Second, we consider the results of *young subjects*. Young adults were able to process each level separately, as shown by Experiments 1a and 2a. They also displayed the "global precedence effect" in both accuracy and latencies in the basic Experiments 1, 2, and 3. In this study, young samples were only used as control groups for the assessment of the effects of age. It thus appears that our young subjects performed as those enrolled by Navon (1997) and many other researchers (see the review by Kimchi, 1992).

Third and finally, we focus on the *results of the elderly* while considering the pattern observed in young subjects. At first glance, the "normal" subsets of elderly enrolled in Experiments 1 and 2 were able to process both levels of stimuli and displayed the global prevalence phenomenon, together with an increased sensitivity to interference in the conflictual condition, and a facilitation in the consistent condition. However, Experiment 3 revealed that these effects of age were artifacts resulting from encoding difficulties (probably due to slight sensory disturbances ; Fozard, 1990). Thus, apparently, the "global precedence effect" per se is not sensitive to age in normal adult subjects. Moreover, the sensitivity of the elderly to interference is not due to a general and nonspecific effect of age on inhibition mechanisms (Hasher et al., 1991).

A major lesson of this series of experiments is that there are subgroups among the elderly. Indeed, from one third to one half of elderly subjects displayed an anomalous pattern of performance by performing at random or worse than at random in the conflictual condition of the local task (Experiments 1 and 2) or in the detection of local differences (Experiments 1a and 2c). This performance could not be accounted for by age, visual acuity, or verbal intelligence. These outcomes cannot be explained within the framework of the present research and constitutes a challenge for future studies. Indeed, the next step of this research program should be to try to understand why some older subjects can do the task efficiently, whereas other cannot. For instance, it would be useful to check experimentally whether this phenomenon is specific to the present experimental design, or if it is the manifestation of a more general increase of sensitivity to interference in some subsamples of elderly people. Indeed, it has been shown that aging could reduce the resistance to interference in very different kinds of experiments, such as the Stroop effect (e.g., Cohn, Dustman, & Bradford, 1984), selective attention (e.g., McDowd & Birren, 1990) inhibition processes (e.g., Hasher & Zacks, 1988), or proactive interference in long-term memory tasks (e.g., Van der Linden & Bruyer, 1991). Experiment 3 began to clarify this point but, obviously, elderly subjects should be submitted to other experimental designs as a matter of control, in order to approach the nature of possible subpopulations of elderly people. Whatever the case may be, one has to take the possibility of several subsamples of elderly subjects into account when this population is enrolled for experimental cognitive tasks.

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