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Original article

Stroop interference and development: Influence of expectation on color-naming response times

Interférence et développement : influence du processus d'expectation sur les temps de dénomination de la couleur

C. Lemercier[a,*], A. Simoës-Perlant[a], J.R. Schmidt[b], C. Boujon[c]

[a] *Toulouse university, 31000 Toulouse, France*
[b] *Department of experimental clinical and health psychology, Ghent university, 25843 Ghent, Belgium*
[c] *Angers university, 49000 Angers, France*

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ABSTRACT

Introduction/objective. – In a sample of 171 participants aged 6 to 18, the present investigation assessed the changes in the size of the Stroop effect with age, and its relationship with the development of expectancies.
Method. – Experiment 1 consisted in four separated tasks, involving naming print colors or reading color words in either a purely neutral or mixed incongruent/neutral condition. Experiment 2 examined changes in the effect of expectation on color naming and word reading processes with age. We manipulated the stimulus set size (from three to seven different neutral stimuli to name or read per condition) in a neutral word-reading and a neutral color-naming task.
Results. – As expected, color naming and word reading develop with age, as revealed by decreased response times. More surprisingly, the magnitude of the Stroop effect was similar across age groups. No reversed Stroop effects were observed (Experiment 1). Moreover, increasing the number of different colors to be named slowed color-naming, but did not impact word reading latencies (Experiment 2).
Conclusion. – A reduction of the cost associated with increasing neutral stimulus set size with age was also observed, revealing the development of expectation processes. The regression analysis linking the data of the two experiments confirmed the impact of expectancies on color-naming but not on word reading. The analysis also supported the idea that the Stroop effect is in part due to expectation.
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RÉSUMÉ

Introduction/objectif. – La variation de l'effet Stroop avec l'avancée en âge et sa relation avec celle de l'expectation ont été étudiées à partir d'un échantillon de 171 participants âgés de 6 à 18 ans et plus.
Méthode. – La première expérience est composée de trois conditions : deux conditions neutres de dénomination de couleur et de lecture de noms de couleur, et une condition mixte (intégrant des items neutres et incongruents) de dénomination et de lecture d'items incongruents. L'expérience 2 examine l'évolution de l'effet d'expectation avec l'âge en lecture neutre et en dénomination neutre, en fonction de la taille de l'ensemble des stimuli à traiter (de 3 à 7).
Résultats. – Comme attendu, les temps de dénomination et de lecture neutres s'accélèrent avec l'avancée en âge. De façon plus surprenante, aucun effet de l'âge n'est observé sur l'effet Stroop et sur l'effet Stroop inversé. Par ailleurs, l'augmentation du nombre de stimuli différents à traiter conduit à une augmentation des temps de dénomination de la couleur et ne produit aucune variation des temps de lecture quel que

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* Corresponding author at: CLLE-laboratoire travail et cognition, UMR CNRS 5263, 5, allée Antonio-Machado, 31058 Toulouse cedex 01, France.
E-mail address: celine.lemercier@univ-tlse2.fr (C. Lemercier).

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soit l'âge des individus. L'analyse révèle enfin une réduction du coût temporel associé à l'augmentation de la taille de l'ensemble des stimuli neutres avec l'avancée en âge, révélant le développement du processus d'expectation.

Conclusion. – Une analyse complémentaire liant les données des deux expériences confirme l'implication du processus d'expectation dans le processus de dénomination de la couleur. Il supporte également l'idée que l'effet Stroop est en partie expliqué par ce processus.

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1. Introduction

Since initial work by Stroop (1935), it has been well established that it is more difficult to name the print color of an incongruent color word (e.g., saying "red" while reading the word BLUE printed in red) compare to naming the print color of a neutral string of letters (e.g., saying "red" to the string of letters "XXX" displayed in red). The increase in response time observed in the incongruent condition is commonly known as the interference or Stroop effect. To correctly name the print color, participants should ignore the word. Given that word reading is more automatic than color naming, reading the word will interfere with color naming. By investigating in the variation in size of the Stroop effect with age (based either on the comparison between blocked or intermixed incongruent and neutral items), the present study aims to stress the significant role of expectation in the variation of color naming response time from neutral to incongruent items.

Prior findings has suggest that participants' ability to resist interference increases with age (e.g., Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Carver, Livesey, & Charles, 2001; Enns & Cameron, 1987; Pennequin, Nanty, & Khomsi, 2004; Rubia et al., 2000; Tipper, Bourque, Anderson, & Brehaut, 1989). As word reading becomes increasingly automatic with age, incongruent words gradually begin to interfere with color naming (Gerstadt, Hong, & Diamond, 1994; MacLeod, 1991; Shiffrin & Schneider, 1977; Schadler & Thissen, 1981). For instance, Schiller (1966) showed, for instance, that the interference effect is minimal for children in first grade, maximal in second and third grade, and then progressively declines starting from fifth grade. When children are too young to read, word meaning does not interfere with color naming. When their reading skills increase, word meaning interferes with color naming. Further, it has also been argued that the inhibition mechanism is not yet mature at eight years old. As such, the magnitude of the interference effect is greater for young participants. With further development, suppression of the distracting word becomes more effective. This hypothesis, related to a deficit in inhibitory control, has also been advanced to explain the increase in the magnitude of the interference effect in the elderly. It has been suggested that older people have more difficulty suppressing the to-be-ignored word dimension while processing the relevant color dimension (Carter, Mintun, & Cohen, 1995; Comalli, Wapner, & Werner, 1962). However, a meta-analysis has demonstrated that the magnitude of the Stroop effect is in fact similar from young adulthood to old age when a general slow-down in processing is taken into account (Verhaeghen and Meersman, 1998). Bub, Masson, and Lalonde (2006) have also proposed a new explanation for the developmental variations in the Stroop effect starting from childhood. By studying the development of Stroop effect from ages 5 to 12, they have demonstrated that younger participants do not have more difficulty suppressing the irrelevant information, but have difficulty maintaining the colored task set. The authors have concluded that children maintain the color-naming task set inconsistently across different trials.

Current measurements of variation in the size of the Stroop effect across age groups involved comparing color naming response time in a neutral condition to an incongruent condition (Bub et al., 2006; Comalli et al., 1962; Pennequin et al., 2004; Schiller, 1966). Nevertheless, there might be two differences between these conditions rather than only one. In addition to a difference in conflict, the stimulus set size for neutral and incongruent items is typically not equated. Typically, there is one neutral item per color (e.g., 4 unique colored items in a four-choice task), while there are multiple incongruent word-color pairings (e.g., 12 combinations of color words and incongruent colors in a four-choice task). As a consequence, it seems possible that neither the inhibitory process nor task-set maintenance are the principal factors of color-naming response time increases, but rather the color-naming process itself. In particular, the increase in the number of items to be named from neutral to incongruent condition could explain a (main) part of the response time variations from these two color-naming conditions. This proposal fits with the idea that during the controlled task, participants learn the "stimulus set", which enables them to predict the response to the item to come on the basis of what has been already been presented (Bruner, 1951; Logan, 1980; Kingstone & Klein, 1991). This view is strengthened by prior studies showing that subjects can incidentally learn new associations during attention-demanding tasks and use them to improve their performance (Graf & Schacter, 1985; Shimamura & Squire, 1989; Schmidt, Crump, Cheesman, & Besner, 2007). The contingency hypothesis of Schmidt et al. (2007) proposes that once participants name the color of a colored word item, they incidentally learn the associations between the dimensions of the item (here, word and color) and then use them to predict the response to come, speeding responding when expectancies are met. For instance, when the item BLUE in red is presented more frequently presented (in high contingency), the association between red color and BLUE word will be incidentally learned, leading the participants to expect the "red" color response when the word "BLUE" is then presented. These studies state that the item set is encoded and/or incidentally learnt during attention-demanding tasks, enabling participants to predict or expect the response to come on the basis of what has already been presented. Since the expectation process is based on the item set, it should be expected that the greater the number of items in a set, the longer the expectation process will take.

If expectation has been observed in adulthood, the chances are high that it is also present from childhood. One of the characteristics of the development of these processes with age is their acceleration. For instance, reading times become faster and faster as the process automates from six years old to adulthood. Thus, as other processes, expectation develops with age, partly explaining in part the variation in response times between children and adults in attentional-demanding task. The effect of the increase in colored stimulus set (regardless the type of colored stimuli: colors, incongruent colored words etc.) in a color-naming task would drive to of an increase in color-naming response time of less and less magnitude with age. This is the alternative hypothesis of the development

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