Working memory and its relation to interference and facilitation effects on a Stroop task in persons with mild cognitive impairments and normal elderly adults

Abstract

The current study investigated working memory(WM) and its relation to interference and facilitation effects using a Stroop-like token task in persons with mild cognitive impairments(MCI) and normal elderly adults(NEA). Both groups demonstrated interference effects. MCI group showed greater interference effects than NEA in the accuracy analysis. The results are consistent with the previous findings (Belleville et al., 2010). Both groups showed no facilitation effects in the accuracy rate. However, they showed longer response times in 75%Congruent than neutral condition. Among WM measures, subtract-2 span task was most highly correlated with the incongruent trials of 75%Congruent condition with the highest cognitive demands.

Introduction

Working memory (WM) refers to a cognitive mechanism which is responsible for maintaining relevant information while operations are performed on goal-related computational tasks (Baddeley & Hitch, 1974). Kane and Engle (2002) developed an executive attentional component of WM by referring to WM as “an attention capability whereby memory representations are maintained in a highly active state in the face of interference and these representations may reflect action plans, goal states or task-relevant stimuli in the environment” (p. 638). Recently, there is increasing support for impairments of WM as an executive attention in early Alzheimer’s disease (AD) (e.g., Belleville et al., 2008). One of the most widely used and accepted terminologies referring to the preclinical phase of AD is mild cognitive impairment (MCI). The most accepted criteria for MCI include the presence of a memory complaint, impaired performance on age-adjusted memory tasks, preserved general cognitive function, an absence of significant functional repercussions, and an absence of dementia (Petersen, 2003). Given that 80% of MCI cases were converted to AD at an annual rate of 10-15%, the concept of MCI was proposed to identify a transitional state between normal aging and dementia (Petersen, 2003). Recent research efforts have been devoted to investigating WM and executive attentional deficits in AD and MCI (e.g., Belleville et al., 2007).

The Stroop task (Stroop, 1935) and its many variants have been widely used to measure executive attention in the psychological literature. In the original Stroop task (Stroop, 1935), participants named the color of a written word. When the color and word are in conflict (“incongruent”: **Red**), color naming is slower and less accurate than when the word is unrelated to the color or when the color and word match (“congruent”: **Red**). According to Kane and Engle (2003), Stroop interference effects reflect difficulties in maintaining the goal of the task by inhibiting the automatically activated word reading processing, resulting in increased errors and prolonged response times on incongruent trials. The authors also reported that Stroop facilitation effects were observed on congruent trials compared with neutral trials, suggesting that the goal-maintenance mechanism is partly responsible for the facilitation effects.

A few studies have investigated Stroop interference effects in MCI. However, none of them examined facilitation effects. Kramer et al. (2006) reported impaired performance, whereas Zhang et al (2007) and Duong et al. (2006) reported a normal Stroop effect. More recently, Belanger et al. (2010) reported that abilities of resistance to interference effects were impaired in MCI and AD compared to healthy older adults with greater impairments in AD than MCI. One of the reasons for inconsistent findings of the Stroop effects in MCI might be due to the employment of simple Stroop tasks, which were not sufficiently WM demanding for MCI. Recently, McNeil et al. (2010) developed a more WM demanding Stroop-like task (CRTT-R-Stroop). However, they did not report relationships between WM measures and CRTT-R-Stroop.

The purposes of the study were to investigate 1) whether MCI group shows greater Stroop interference effects and reduced facilitation effects than normal elderly adults (NEA) in a Stroop-like Token Task with greater WM demands than the clinical Stroop task and 2) whether WM measures are related to Stroop effects in MCI and NEA

Methods

Nineteen individuals (13 NEA and 6 MCI) participated in the study (We continue to collect more data). Persons with MCI met Petersen's most recent criteria (Petersen, 2003) based on the standardized Seoul Neuropsychological Screening Battery (SNSB) (Kang & Na, 2003) and clinical diagnosis carried out by trained neurologists. They showed impairments on memory tests and/or other cognitive domains (1.5SD below normal), preserved basic day to day functioning, and insufficient findings to warrant a diagnosis of dementia. The NEA group showed normal range of performance on the SNSB and Korean Mini-Mental State Examination (K-MMSE) (Kang, Na, & Hahn, 1997). They had no history of brain injury, a self-report of normal language development.

All of the participants completed six short-term and working memory tasks: Digit Forward (DF), Digit Backward (DB), Word Forward (WF), Word Backward (WB), Subtract-2 span task, Alphabet span task (See Table 1).

STT was a modified Subtest 1 from McNeil et al. (2010)'s CRTT-R-Stroop. For example, "**red** **square**" was presented on top of an LCD touch-screen monitor with the display of ten tokens consisting of five different colors and two shapes in the bottom of the screen. Participants were instructed to touch a relevant token displayed in the monitor. STT was composed of three difference conditions: 1) Neutral ( circle), 2) 75%Congruent, and 3) 0%Congruent. Participants completed a total of 240 trials with 80 per each condition.

Response times (RT) and accuracy rate were obtained. As Kane and Engle (2003) noted, interference effects and facilitation effects are not independent. However, as is normative in Stroop research, we analyzed these effects separately by contrasting incongruent trials with neutral trials for interference effects and congruent with neutral trials for facilitation effects.

Results

1. Interference effects

Two separate two-way mixed ANOVAs (Group x Condition: Neutral, 0%Congruent, 75%Congruent) were performed for the accuracy rate and RT of the incongruent trials. For the accuracy rate (Figure 1), there were significant main effects for condition, $F(2, 34)=11.25$, $p<.0001$, and Group, $F(1, 17)=6.47$, $p<.05$ with higher accuracy in NEA than MCI. Neutral condition generated significantly higher accuracy rate than 0%Congruent and 75%Congruent conditions, which were not significantly different. The two-way interaction was also significant, $F(2, 34)=5.04$, $p<.05$, with greater group differences in 0%Congruent and 75%Congruent conditions compared to the neutral condition. For the RT (Figure 2), a main effect for the task was significant, $F(2, 32)=34.03$, $p<.0001$ (Neutral<0%Congruent<75%Congruent). Main effect for Group and the interaction were not significant.

2. Facilitation effects

Two separate two-way mixed ANOVAs (Group x Condition: Neutral, 75%Congruent) were performed for congruent trials. For the accuracy (Figure 3), none of the effects were significant. For the RT (Figure 4), main effect for condition was significant, $F(1, 17)=34.43$, $p<.0001$, with longer RT in 75%Congruent than Neutral condition. The two-way interaction was also significant, $F(1, 17)=5.07$, $p<.05$, with greater group differences in 75%Congruent than the neutral condition. A main effect for Group was not significant.

3. Correlations among WM measures and Stroop conditions

Pearson correlation coefficients were computed for accuracy rate and RT. For the accuracy rate (Table 2), DF, Subtract-2, and alphabet-span tasks were significantly and positively correlated with Neutral condition, and WB with incongruent trials of the 75%Congruent condition. For the RT (Table 3), DF, DB, and alphabet-span were significantly and negatively correlated with Neutral condition, and DF, DB, WB, and Subtract-2 with 0%Congruent, and DF and Subtract-2 with congruent trials of the 75%Congruent, and subtract-2 with incongruent trials of the 75%Congruent condition.

Discussion

Both groups demonstrated interference effects on Accuracy rate and RT. MCI group showed greater interference effects than NEA in the accuracy analysis. The results are consistent with previous findings (Belleville et al., 2010). Both groups showed no facilitation effects in the accuracy rate. However, they showed longer RT in 75%Congruent than neutral condition. These results are not consistent with findings from younger adults (Kane & Engle, 2003), speculating that age-related facilitation mechanisms might differ from those of younger adults. Among WM measures, subtract-2 span task was most highly correlated with the incongruent trials of 75%Congruent condition with the highest cognitive demands.

References

Baddeley, A., & Hitch, G. (1974). Working memory. In G.A. Bower (Ed.), *Recent advances in learning and motivation* (Vol. 8, pp. 47-90). New York: Academic Press.

Belanger, S., Belleville, S., Gauthier, S. (2010). Inhibition impairments in Alzheimer's disease, mild cognitive impairment and healthy aging: Effect of congruency proportion in a Stroop task. *Neuropsychologia*. 48, 581-589.

Belleville, S., Bherer, L., Lepage, E., Chertkow, H., & Gauthier, S. (2008). Task switching capacities in persons with Alzheimer's disease and mild cognitive impairment. *Neuropsychologia, 46*(8), 2225-2233.

Belleville, S., Chertkow, H., & Gauthier, S. (2007). Working memory and control of attention in persons with Alzheimer's disease and mild cognitive impairment. *Neuropsychologia, 21*(4), 458-469.

Duong, A., Whitehead, V., Hanratty, K., & Chertkow, H. (2006). The nature of lexico-semantic processing deficits in mild cognitive impairment. *Neuropsychologia, 44*(10), 1928-1935.

Kane, M. J. & Engle, R. W. (2003). Working-memory capacity and the control of attention: the contributions of goal neglect, response competition, and task set to stroop interference. *Journal of Experimental Psychology: General*, *132,* 47-70.

Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin and Review*, *9*, 637-671.

Kang Y, Na DL, Hahn S. (1997). A validity study on the Korean Mini-Mental State Examination(K-MMSE) in dementia patients. J Korean Neurol Assoc, 15, 300-308.

Kang Y, Na DL. (2003). Seoul Neuropsychological Screening Battery (SNSB). Incheon: Human Brain Research & Consulting Co.

Kramer, J. H., Nelson, A., Johnson, J. K., Yaffe, K., Glenn, S., Rosen, H. J., et al. (2006). Muptiple cognitive deficits in amnestic mild cognitive impairment. *Dementia and Geriatric Cognitive Disorders, 22*(4), 306-311.

McNeil, M.R., Kim, A., Lim, K. Y., Pratt, S.R., Kendall, D., Pompon, R., et al. (2010, May). *Automatic activation, interference and facilitation effects in persons with aphasia and normal adult controls on experimental CRTT-R-Stroop*. Poster session presented at the annual meeting of Clinical Aphasiology Conference, Keystone, CO.

Petersen, R.C. (2003). *Mild cognitive impairment*. Oxford University Press

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643-662.

Zhang, Y., Han, B., Verhaeghen, P., & Nilsson, L. G. (2007). Executive functioning in older adults with mild cognitive impairment: MCI has effects on planning, but not on inhibition. *Aging, Neuropsychology, and Cognition, 14*(6), 557-570.

Table1. Demographic data and working memory measures for MCI and NEA

	NEA	MCI
Age (yrs.)	71 (4.8)	70 (3.2)
Education (yrs.)	9 (5.3)	7 (2.7)
DF	5.61 (1.66)	4.67 (1.21)
DB	3.92 (0.95)	3.67 (1.21)
WF	4.38 (0.50)	4 (0.89)
WB	3.31 (0.63)	3 (0)
SUB2	3.62 (1.24)	3.58 (0.58)
ALP	3 (1.20)	2.08 (1.74)

NEA=Normal Elderly Adults; MCI=Mild Cognitive Impairments; DF=Digit Forward, DB=Digit Backward, WF=Word Forward, WB=Word Backward, Sub2=Subtract-2 span task, ALP=Alphabet span task

Table 2. Correlation Coefficients for accuracy rate among working memory measures and Stroop conditions

	Neutral	0%Contruent	Congruent trials of 75%Congruent	Incongruent trials of 75%Congruent
DF	**0.54***	0.24	0.16	0.25
DB	0.3	-0.17	0.15	0.09
WF	0.17	0.23	0.07	0.15
WB	0.44	0.21	-0.25	**0.48***
SUB2	**0.54***	0.05	-0.12	0.06
ALP	**0.53***	0.35	-0.27	0.31

*: significant (*p* <.05)
DF=Digit Forward, DB=Digit Backward, WF=Word Forward, WB=Word Backward, Sub2=Subtract-2 span task, ALP=Alphabet span task

Table 3. Correlation Coefficients for response time among working memory measures and Stroop conditions

	Neutral	0%Contruent	Congruent trials of 75%Congruent	Incongruent trials of 75%Congruent
DF	**-0.68****	**-0.63****	**-0.52***	-0.3
DB	**-0.57***	**-0.61****	-0.44	-0.45
WF	-0.29	-0.67	-0.28	-0.25
WB	-0.33	**-0.5***	-0.28	-0.32
SUB2	**-0.63****	**-0.64****	**-0.77****	**-0.68****
ALP	**-0.55***	-0.41	-0.34	-0.32

*: significant (*p* <.05)
**: significant (*p*<.01)
DF=Digit Forward, DB=Digit Backward, WF=Word Forward, WB=Word Backward, Sub2=Subtract-2 span task, ALP=Alphabet span task

Figure 1. Interference effects in accuracy rate for both groups

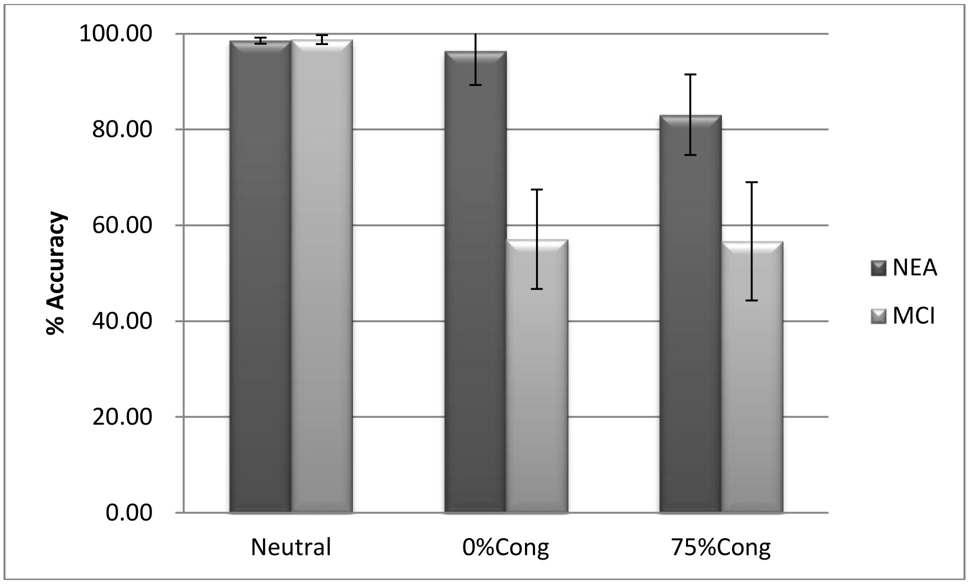

Figure 2. Interference effects in response times for both groups

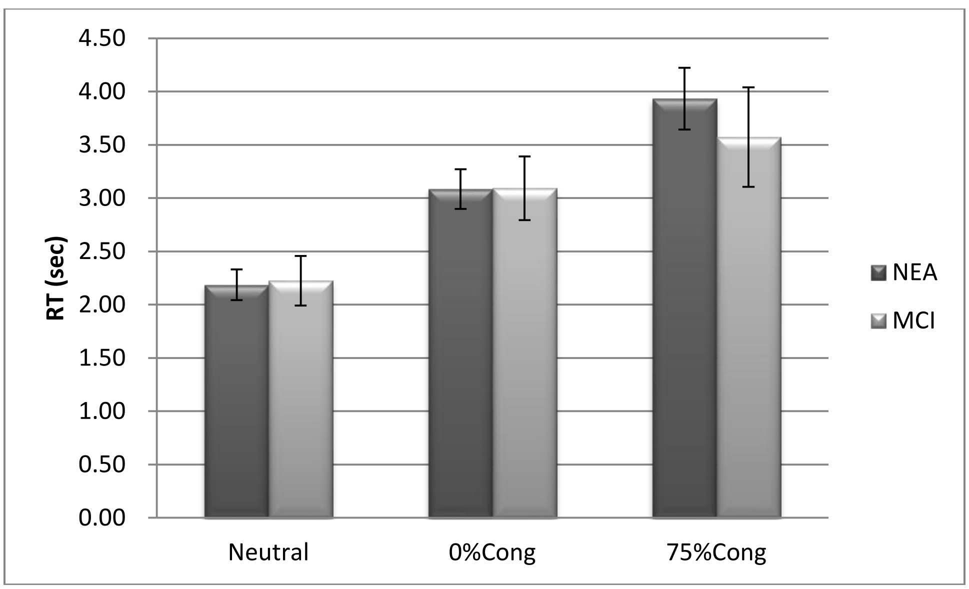

Figure 3. Facilitation effects in accuracy rate for both groups

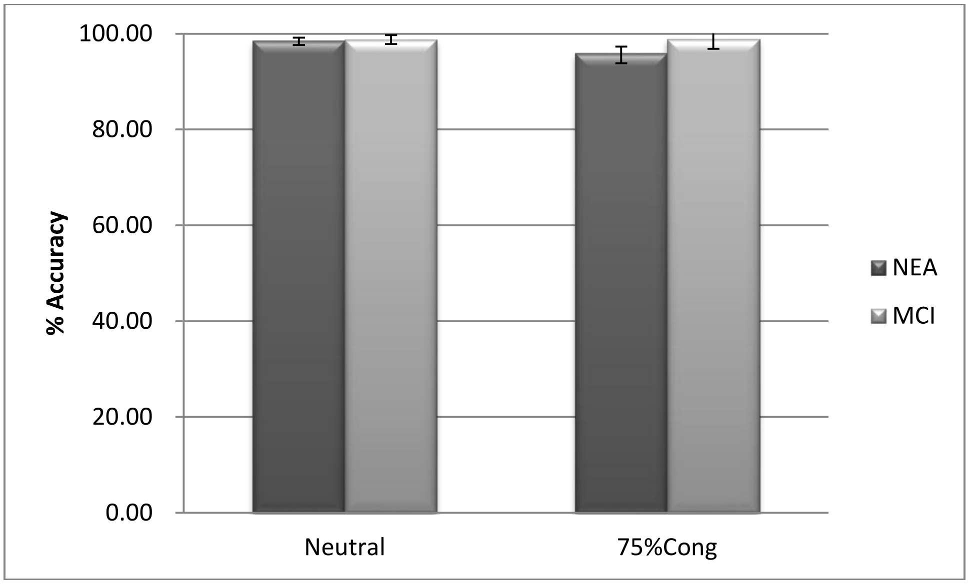

Figure 4. Facilitation effects in response times for both groups