Original Research Article

Influence of stimulus location information on performance assessed by Simon task: Does Simon effect vary with age?

Priyadharshini V[1], Anbuselvi Mattuvar Kuzhali S[2], Ratna Manjushree J[3]

[1]Post Graduate, Institute of Physiology and Experimental Medicine, Madras Medical College, Chennai,
[2]Assistant Professor, Institute of Physiology and Experimental Medicine, Madras Medical College, Chennai,
[3]Professor & Head, Thiruvannamalai Medical College, Thiruvannamalai, Tamilnadu.

Abstract

Introduction: Simon tasks are tests to study the cognitive control and inhibition process. Amongst stages of information processing: stimulus identification, response selection, and response execution, the response-selection is assessed by Simon effect. How the stimulus properties change the response? How the location information does affect the response when it is irrelevant to the task? We intended to identify how this judgement of stimuli varies with age. **Aim:** To estimate and compare the reaction time in milliseconds between the compatible / incompatible stimuli and Simon effect of Simon task amongst different age groups.
Materials and methods: 176 clinically healthy of age (18-50) years of both males and females with basic computer knowledge were recruited. After clear instructions, all subjects were asked to perform software based cognitive tasks, stimulus-response compatibility test (Simon effect) with 40 trails, Right/Left stimulus, and compatibility reaction. Data were recorded as reaction time of the average responses in Simon task and analyzed using SPSS. **Results and discussion:** Reaction time increases more for incompatible stimuli than compatible stimuli (p=0.000), and increased more for older individuals than young adults. Simon effect is measured as increased cognitive load which emphasize cognitive error processing/resolving information during each stimulus. **Conclusion:** Responses are speeded when the stimulus is displayed on the same side as the response compared to when it is displayed on the opposite side. This effect of spatial correspondence decreases with increase in age.
Key words: Attention, Response-selection, Simon effect

Corresponding Author
Dr.AnbuselviMattuvarKuzhali. S, Assistant Professor, Institute of Physiology and Experimental Medicine,Madras Medical College, Chennai.
Mobile no. 9940840760,
E mail: dranbuselvimk@gmail.com

Introduction

Despite our understanding about multitasking actions, its underlying cognitive mechanisms are far from being clearly understood. However, recent studies had proven concepts on how perception and action are inter-twined, how individuals select task-relevant information, could predict forth-coming actions and integrate as well as interpret the predicted actions of self and

others.[1,2]As humans we spend most of our time interacting and communicating with others, a major function of human cognition is likely to coordinate those action. What is unclear, is how processing information about one's own and/or others activities requires a complex "social"mechanism and whether is it sufficient as claimed by some authors.[3,4]

However, this research had studied on individuals performing a cognitive or behavioral task in isolation. In human experiments to evaluate cognitive-information processing, cognitive tasks are given that gain access to basics of cognition by providing clues to fundamental process of attention.[5]The ability to control attention relies on how the information as a stimulus has been identified, processed and then remembered. Cognitive flexibility is usually described as one of the executive functions: two subcategories of cognitive flexibility are task switching and cognitive shifting, depending on whether the change happens unconsciously or consciously, respectively.[6]Cognitive flexibility varies during the lifespan of an individual. In addition, certain clinical conditions like obsessive–compulsive disorder are well associated with reduced cognitive flexibility.[4]

When engaging in multitasks or while performing a complex coordinated action, individuals are often required to perform complementary parts of a given task, i.e., taking turns rather than acting at the same time. Executive functioning includes other aspects of cognition, including inhibition, memory, emotional stability, planning, and organization. Cognitive flexibility is highly related with a number of these abilities including inhibition, planning and working memory.[6,7]One of the extensively studied cognitive tasks in experimental psychology is the Simon task and its well suited to study the visuospatial attention and inhibitory control in processing information.[8] The Simon task basically examines the selective attention process part of cognition, where the conflicts appear in terms of mapping between a given stimulus and its appropriate response.[9] While measuring the performances, the compatibility between the stimuli and its obtained responses produces clear effects, and any errors or change in stimulus-response (S-R) compatibility can provide evidence on how selective attention functions.[10] Thus, the Simon task works on the basis of measuring the control over simple S-R mapping which in turn depicts the visuospatial attention and inhibitory control.[11]In the current study, computer based software to perform cognitive task was used.[12,13]

Studies done using Simon task suggests that, the Simon effect relies primarily on the response selection and execution stage of cognitive information processing.[14-16]Evidenced with radio-imaging studies, recording of cortical potential had shown the presence of neuronal firing in primary motor cortex when individuals performed the Simon task.[17]If an individual had to give a compatible response then there has to be a partial activation of the associated motor cortex. For the same person to respond to an incompatible stimulus then the pre-activation of the cortex relative to spatial orientation has to be inhibited.[18]

We intended to assess the brain reaction time and ability to inhibit cognitive interference that occurs during stimulus processing across different age groups. How the stimulus properties change the response? How does the stimulus-location information affect the response when it is irrelevant to the task? We intended to identify how this judgement of stimuli varies with age.

Aim

To estimate and compare the reaction time in milliseconds between the compatible /

incompatible stimuli and Simon effect of Simon task amongst different age groups.

Materials and Methods

Selection of sample and participants

This is an analytical cross-sectional study, was started after obtaining institutional ethics clearance and written informed consent from all the participants. A statistically adjusted sample size of 176 participants of 18 to 50 years age of both genders were selected from the community.

Inclusion criteria

About 176 participants who were clinically normal healthy individuals of age 18 years to 50 years of both gender with basic computer knowledge, normal visual acuity and colour vision were recruited.

Exclusion criteria

The participants who were of age <18 years and > 50 years age, who were with any chronic illness, metabolic disorders, neurological or psychiatric disorders, colour blindness or visual defects were excluded. Those who had any refractive errors and using spectacles were also excluded. Any history of drug intake except vitamin medications was excluded.

Apparatus and materials

To perform the cognitive task, the experiment was run on a HP advanced computer with a standard 14-inch monitor; using a validated computer-based software.[12,13] Participants viewed the display from an approximate distance of 50 cm. The display consisted of a cue (centrally fixed cross) on the screen (0.5cm X 0.5cm) and a word stimulus (Measuring approximately 3cm in length and 1.5cm in height). The locations of the words (left and right) were situated on the horizontal plane from the centrally fixed cross (cue) area. The centrally fixed cross and words were presented in yellow print on a black background.

Procedure

After clear instructions to the study group, all the participants were asked to fill up a self-made questionnaire that consists of socio-demographic profile, clinical history and underwent a thorough clinical examination. Visual acuity and colour vision were approximately tested with Snellen chart, Ishihara chart and Holmgren wool test, only to confirm that all the participants had a normal 6/6 vision with a normal colour vision. Participants were asked to perform the cognitive task in laptop monitor (Hp advanced, 14-inche screen with medium display) using a validated software based cognitive assessment task – Simon task.[5,6]

Performance of Simon Task

The Simon task is a stimulus-response compatibility test, which has 40 trails, a cue(centrally fixed cross) will be displayed for a few seconds, after which the word stimuli appears on the screen as ‘left’ and ‘right’. Participants were instructed to ignore the cue and strictly respond only to the word stimuli. Very specifically, participants were instructed to press the left button ‘A’ when a word ‘left’ appeared and to press the right button ‘L’ when a word ‘right’ appeared. Instructions are such, when the stimuli ‘left’ appear either on both sides, the response should be made by the left key press.

Interpretation of the Simon Task

In the current study, participants made a button press response after identifying the stimulus based on its location (i.e., respond with a left or right key press to the displayed word). Mostly the observations are clear when the word ‘left’ appears on the same side of the participant. The conflicts on the observations are assumed when the word ‘left’ appears to the right side of fixation

and when the word 'right' appears to the left side of fixation, thus creating interference between the stimulus and its response. The critical observation is considered as a compatible response, when the stimulus and its location match (e.g., word 'left' on the left side of fixation), here the individuals were expected to respond faster. When the location of the stimulus relative to its fixation conflicts, it is considered as incompatible response (e.g., word 'left' appears to the right of fixation), then the individuals tend to respond slower. From this task, Simon effect is typically expressed as the reaction time (RT) cost of responding to an incompatible stimulus (milliseconds) relative to a compatible stimulus (milliseconds).

Statistical analysis

Data recorded were the reaction time of the average response speed in compatible and incompatible condition of Simon task. Data analyses were performed with the statistical software package SPSS Version 24.0 for windows (USA). The normality distribution of all variables was tested with Kolmogorov–Smirnov test. Variables were measured over time in the same patient. Comparison of variances within all groups to variances between groups was analyzed using one-way ANOVA with Tukeys multiple Post-hoc analysis as appropriate. Whether the changes of Simon effect over the different age groups vary between male and female was assessed using factorial analysis, adjustment for multiple comparisons-Bonferroni. The mean difference is significant at the .05 level for all analyses.

Results and discussion

The results from the Simon task for different age groups can be viewed in several ways. In this study, about 176 clinically healthy subjects were tested for the performance of cognitive tasks. The mean of baseline characteristics amongst the study group were as depicted in Table.1. There were not much significant difference found in the anthropometric characteristics, age and sleep hours between the study groups.

Table. I.

Comparison of age, anthropometric characteristics and sleep hours between groups.

Parameter	18-20 yrs. (n=44)	21-30 yrs. (n=44)	31-40 yrs. (n=44)	41-50 yrs. (n=44)	*p
Age (years)	18.6±1.6	26.3±4.2	36.9±3.9	45±4.1	0.51
Weight (kg)	76.8±5.82	50.9±2.43	51.63±2.61	61.3±1.1	0.46
Height (m)	1.56±0.08	1.55±0.06	1.4±0.5	1.5±0.3	0.43
BMI (kg/m2)	31.82±1.93	21.19±1.2	20.6±1.6	22±3.3	0.31
Sleep hours	7.8± 1.2	8.2±1.1	7.4±0.9	7.9±2.5	0.67

Data presented as mean, standard deviation.BMI is body mass index; *p<0.05: one-way ANOVA.

Table 2:

Comparison of the stimulus-response conflicts between the groups.

RT of variables	Age group in years	N	Mean	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Compatible	17-20	30	691.46	27.945	634.13	748.8
	21-30	30	915.33	79.208	750.11	1080.56
	31-40	30	1322.21	202.546	884.64	1759.79
	41-50	30	1241.8	252.434	540.93	1942.67
	51-60	28	1432.65	381.683	641.09	2224.21
	61-70	28	1305.6	386.306	233.04	2378.16
	Total	176	1070.65	103.407	865.36	1275.94
Incompatible	17-20	30	684.32	36.055	610.34	758.3
	21-30	30	780.95	45.383	686.29	875.62
	31-40	30	840.74	37.432	763.11	918.37
	41-50	30	1087.6	239.155	423.6	1751.6
	51-60	28	1194.29	222.862	712.82	1675.75
	61-70	28	1203.8	276.528	436.04	1971.56
	Total	176	865.36	44.036	777.94	952.79

RT is reaction time in milliseconds. Compatible: compatible response; incompatible: incompatible response.

*p<0.05: one-way ANOVA.

Table 3:

Dependent variable Simon effect over age*sex interactions:

Age groups in years	sex	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
17-20	Male	93.773	76.608	-58.571	246.117
	Female	132.346	112.143	-90.662	355.355
21-30	Male	80.857	152.825	-223.052	384.766
	Female	224.857	108.064	9.961	439.753
31-40	Male	775	165.07	446.74	1103.26
	Female	174	98.066	-21.015	369.015
41-50	Male	549.2	180.825	189.61	908.79
	Female	275.444	134.779	7.422	543.467
51-60	Male	67.333	233.444	-396.896	531.562
	Female	424.5	285.909	-144.062	993.062
61-70	Male	75.333	233.444	-388.896	539.562
	Female	335.5	285.909	-233.062	904.062

Table.4:
Binary analysis of interference with age*sex.

Source	Mean Square	F	Sig.	Partial Eta Squared
Age	419449.852	2.566	0.033	0.13
Sex	513.815	0.003	0.955	0.21
Age * sex	419577.312	2.566	0.033	0.13

The data in Table.3, Table.4 shows the presence of the age-sex interaction over Simon effect. It suggests that younger adults and males showed a significant decrease in the Simon effect as RTs increase, whereas older adults display an increasingly larger Simon effect. The reaction time lengthens to choose the correct response in elderly age suggesting a decreased cognitive load.

1. Analysis of Simon Task:

As evidenced with prior research on the Simon task, the primary dependent measure is the reaction time (RT) for the identification of the word irrespective of its location in the two different trials (compatible and incompatible).The difference between the reaction time of compatible and incompatible response is noted as Simon effect. Also, in order to take into account general slowing of reaction time from older age group relative to the younger age groups, we transformed the RTs into standardized z scores; conclusions regarding the magnitude of the Simon effect can be made on the basis of these measures in effect to overall slowing.[16] Finally, we explored whether there were age differences in error rates among healthy younger and older age groups in the Simon task. Supposedly, error rates were disproportionately higher in individuals with AD as compared with healthy older adults.[17]

2. Reaction Time analysis:

The reaction time of the responses were as depicted in table2.The observations were considered as a compatible response if the stimuli and its location are on the same side. When the stimuli relative to its location contradict, it is recorded as an incompatible response. Assumed that, in the conflict condition, for an individual to respond faster, the mapping or the so-called spatial correspondence (location) of the stimulus has to be inhibited.[14]

RTs that were more than 2.5 standard deviations from the mean for each participant were removed, and this resulted in the exclusion of less than 1.8% of RTs for each group. The RT of compatible and incompatible response is significantly high above 50years age group. This infers that the ability to inhibit irrelevant information (location) for producing the response is reduced in 50years and above.

There was a significant main effect of between groups and within groups difference for compatible response was observed to be F=1.78, MSE=1770996.151 and F=0.822, MSE=9851796, p.0.019, respectively indicating that the age groups differed in overall RTs for compatible response. Similarly, a significant main effect of between groups and within groups difference for incompatible response was observed to be F=4.31, Mean-square=683121.9 and F=0.845, Mean-square=158549.8, p.0.000, respectively indicating that the age groups differed in overall RTs. RT for compatible response were significantly faster than compatible response(p 0 .001).

3. Analysis of Simon effect with age*sex interactions:

To further examine the age group and sex interaction over the interference effect, i.e. the

differences in RTs, whether the change of Simon effect over the age groups vary between male and female, we conducted a factorial model analysis of variance (2-ANOVA) as shown in Table.3

Discussion

Cognitive testing was done on 176 clinically normal healthy participants using a software-based Simon task. Their processing speed, error rates, spatial correspondence (stimuli location) were assessed with the reaction time (milliseconds) in Simon task.

i. Type of stimuli used:

Various studies on Simon effect had been used: (i) stimuli that necessitated learned associative responses (e.g., the response is indicated towards color of the stimuli) and (ii) some studies used the directionality of the arrows relative to fixation point (e.g., participants must respond to the direction of the arrow).[19] The current study software was focused on the word stimuli 'left' and 'right'.[12.13] Its been clearly proved that the Simon effect is due to the inhibitory control in selective attention, a relatively late stage of information processing.[15-17]

Simon task measures the ability to ignore the irrelevant stimulus by choosing the correct response. The factors influencing the response are response modality, response timing with respect to relevant information, spatial coding and attention. It includes the strength of association of irrelevant information and temporal overlap of resulting response activation. In this study the irrelevant stimulus is the 'cue' (centrally fixed cross) that acts as a distraction.

ii. Simon effect:

Consistent with prior research, younger adults show a reduced Simon effect at longer RTs than older age group as shown in Table.2. This strongly implies that when controlled processing is present in young adults and males, the irrelevant stimuli (cue in this study) have decayed over time; hence the Simon effect is reduced. However, older adults do not show this trend because the irrelevant response code information (cue) still disturbs the processing. This is reflected in older age groups as increased Simon effect with longer RTs. This finding is important in terms of supporting a two-mechanism account of the Simon effect which states that older adults have difficulty in selecting and controlling response pathways.[4-7] The two-stage model posits that the Simon effect is related to both an initial fast, transient effect and a slower, controlled component. It was assumed that older adults do not (or cannot) utilize the slower, controlled process to reduce the Simon effect at longer RTs. Overall, in the study group, men had lesser reaction time than women, this is probably because of their faster adaptive capacity. Females had less error rates but increased reaction time.

The mechanism hypothesized behind Simon effect is that normally, the location of stimulus directly influences the response-selection phenomenon due to automatic tendency to react towards the source of stimuli. However, any change in spatial compatibility, i.e. orientation of the stimuli the response-stage of information processing.[20]The primary interference occurs only when both stimulus and response does not correspond. This Simon effect indicates the cognitive load. The areas involved are frontal cortex, anterior cingulate cortex and angular cortex involving visual-motor integration.[21]

iii. Variations in compatible and incompatible responses:

Amongst the study group, the compatible response was faster than the incompatible response in the younger age group compared to the group above 50years. Scientifically, focusing on

the stimuli location (spatial coding) and shifting the attention to produce a response usually distracts, which would reflect on the RT of incompatible response. For this, the automatic response tendencies must be inhibited unless they are known to be correct.[122]The reaction time slowly increases in 50s. Based on Inhibition Deficit theory, this is due to the high cognitive load (slower processing time) in elderly age group that creates error resulting in lengthening of the reaction time[23, 24]

Direction of stimulus +Amount of interference→Degree of Automaticity + Attention control.[20-23]

Many theories had been proposed, some infer that normal aging decreases the ability of the people to inhibit the irrelevant response to arrive at the target response.[23-26] Their reaction latencies are increased when compared to young adults but error rates remain the same.

Conclusion

Responses are speeded when the stimulus is displayed on the same side. The purpose of this study was to examine how the attention strategies in information processing have an impact when the spatial correspondence of the stimuli is not constant and the varied response is affected by the location of stimuli. Moreover, observations from this study might provide useful information regarding the delineation in attention control system with healthy aging. Merely by extensive practice, the fundamental human cognitive information processing can be altered (brain plasticity).

Limitations

The reduced sample size in each age group, inadequate functional imaging studies on cortex was the limitations of the study. Though an honest attempt was made only to identify the existing attention control strategies amongst different age groups.

Acknowledgments

This study was not funded by any organization. Our sincere gratitude to Professor GijsbertStoet for creating this software with which we were able to do this study.

Conflict of interest: Nil

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