July 2016, Vol.42, No.2, 337 - 343.

Relationship between Attention and Inhibition: Are they Two Sides of the Same Coin?

Susan Thomas, Shobini L. Rao and B. Indira Devi
Bangalore, India

The aim of the present study was to explore the relationship between two tests of attention and two tests of motor inhibition. The four tests studied were: Figural Visual Scanning Test, Auditory Target Detection Test, Stop Signal Test and Go/ No Go Test. These were administered on a normal sample of 60 subjects (30 males and 30 females). They were in the age range of 16-30 years, who had completed ten years of formal education. After administration of all the tests, a correlational analysis was performed to find out the relationship between the variables. Results showed a significant association between the two processes of attention and inhibition. They are related and a deficit in one process can influence the other.

Keywords: Attention, inhibition, neuropsychological assessment.

Attention and inhibition are basic processes, which help in further cognitive processing. Attention and inhibition are often defined and classified in overlapping ways in testing as well as in clinical formulations (Barkley, 1997). Attention is the ability to focus on relevant elements of sensation for further cognitive processing while simultaneously excluding others (Vecera & Rizzo, 2004). Attention is not uni-dimensional, it involves selection, sustenance and ability to vary or divide based on need. The process of attention is not limited to a single brain area, though evidence suggests that there is a predominant influence of the prefrontal area (Daffner et al, 2000). On the other hand, inhibition involves the ability to avoid further processing of stimuli, which are to be ignored (Kok, 1999). It is often considered as an active process, but this concept is challenged by others (Aron, 2007). However, involvement of the frontal cortex in inhibitory process is widely accepted (Dimitrov et al, 2003; Roberts & Wallis, 2000). Both attention and inhibition involve ‘to be attended’ and ‘to be ignored’ stimuli. The modulation of attention requires active facilitation of attended events and active inhibition of irrelevant events (Kok, 1999). However, while drawing conclusions in neuropsychological testing, there is a tendency to report them as independent entities.

Some efforts have been made to study the relationship between these two important and basic cognitive processes but, much remains to be understood. Studies that examine the brain correlates of attention and inhibition using event related potentials found that there is a correlation between prepulse inhibition and selective but, not sustained attention tests (Bitsios & Giakoumaki, 2005). Araki, Nasai, Nakagome, Fukuda, Itoh, Koshida, Kato and Iwanami (2005) studied the brain electric activity for active inhibition of auditory irrelevant information. They found that the scalp current density (SCD) values were significantly larger than those for the relevant stimuli. This data points towards the involvement of an active inhibitional process in attention. However, there can be differences in the relationship based on the modality of the stimuli also (De Ruiter, Kok & Van Der Schoot, 1998). These studies point to the need to examine the various aspects of these processes carefully to delineate the functions that are being assessed during testing, as they are closely related.

Rationale for the study: Attention and inhibition, in routine neuropsychological testing seem to be complimentary to each other and the tests are similar. In both tasks, targets and distracters are presented and for successful performance, responding to the relevant stimuli and ignoring or inhibiting the response to the irrelevant stimuli is required. Thus, the tests that measure attention have inhibitional components in them and vice versa. Both the processes also seem to involve the frontal cortex, though inhibition is considered as a function related to inferior frontal cortex (Menon et al, 2001; Rubia et al, 2001). However, the specificity of this structure–function relationship is inconclusive, and studies show that attention is also related to this area (Bledowski et al, 2004). Thus, the structural correlates of these two functions also seem to overlap. Both the the functions, attention and inhibition thus, seem to have the same functional aspects, structural aspects and similar tests to assess them. The similarity of these two functions are so close that researchers often hypothesize that they are two sides of the same coin (Miller & Cohen, 2001; Mostofsky & Simmonds, 2008). Hence, it is important to examine whether they are indeed two sides of the same coin, with different names, or two independent functions. It is necessary to explore the relationship between these functions to have meaningful results while testing and interpretation of these results. The differences and similarities should be kept in mind to be able to draw conclusions regarding the adequacies or impairments in attention and inhibition. The studies, which explore the relationship between these functions use event related potential analysis or functional magnetic resonance imaging, which may not be readily available in routine neuropsychological testing. This study was an attempt to understand the relationship between tests of attention and inhibition and possible independence in neuropsychological testing using paper and pencil tests, as they are two important, primary functions that are required for adequate cognitive functioning.

The aim of the study was to explore the relationship between tests of attention and inhibition. The objectives of the study were: (1) to explore the relationship between two tests of attention, the Figural Visual Scanning Test (Wilkie et al., 1990) and Auditory Target Detection Test (Gopukumar & Rao, 2005); (2) to explore the relationship between two tests of inhibition, Stop Signal Test (Devender Kumar, 2000) and Go/No-go Test (Devender Kumar, 2000) and (3) to explore the relationship between the two tests of attention and two tests of inhibition.

Method

Sample:

The sample consisted of 60 right handed normal volunteers including 30 males and 30 females. The mean age of the sample was 21.07 years with a standard deviation of 4.95 and the mean education was 8.42 years with a standard deviation of 2.61. The subjects had no history of any psychiatric, neurological or neurosurgical disorders and had normal or corrected vision and hearing.

Tools:

Socio demographic Data Sheet

This sheet was prepared by the researcher to collect socio-demographic details of each subject included in the sample viz. name, age, sex, occupation, address and education level.

Screening tool:

Edinburgh Handedness inventory (Old field, 1971)

Edinburgh Handedness Inventory was used to determine handedness, as only right-handed subjects were included in the sample. The inventory consisted of 10 activities, like writing, using a toothbrush and striking a match and required the participant to indicate which hand was preferred for these activities. A laterality quotient was obtained by dividing the difference between total activities with right hand and total activities with left hand by summing the total items done with right hand and left hand and multiplying the score with 100. All subjects recruited in the study had a laterality score of 100.

Tests to measure attention:

Figural Visual Scanning Test (Wilkie et al, 1990). Figural Visual Scanning test was developed and used in association with studies on cognitive impairment in Human Immunodeficiency Virus (HIV) (Wilkie et al, 1990, Wilkie et al, 2004). This test has been used in India with HIV infected individuals and has been found useful (Gupta et al, 2007). The test included 20 sets of meaningful and non meaningful figures, five on each sheet of paper. The target was given on the left and five choices on the right. The subject had to choose the target from the five choices. The total time, number of correct answers and errors were recorded. The test retest reliability correlation of the test was 0.93, and the test was found to have discriminant validity by being able to distinguish between individuals with focal brain lesions and the normal (Thomas, 2005).

Auditory Target Detection Test (Gopukumar & Rao, 2005)

This test was developed in association with a study examining AIDS related cognitive deficits (Gopukumar & Rao, 2005). A list of 120 concrete nouns was presented to the subject auditorily by an audio cassette player. The stimuli were words, which are in common use and not pertaining to any category. The target word ‘rain’ was randomly repeated 20 times in the list, which was to be responded to by tapping the subject’s finger on the table. This test is available in English, Hindi, Kannada, Tamil, Telugu and Malayalam. The test retest reliability correlation was 0.51 and the test was found to have adequate discriminant validity (Thomas, 2005). Scoring was in terms of hits, omissions and commissions.

Tests to measure inhibition

Stop Signal Test (Devender Kumar, 2000)

The stop signal task focused on the stop signal paradigm, in which subjects were given a primary task to perform and on occasions, a Stop Signal was presented that indicated not to respond on that trial. This test was developed as a part of standardizing a battery of neuropsychological assessments. The stimulus was a list of double digits, between 10 and 99. A total of 89 digits were used. The digit 10 was the target and these targets were randomly inserted into the list, half of which were coupled with the stop signal, i.e., they were presented at a higher volume than the other digits (loud 10). They were predesigned targets, to which the subject was not required to respond. The rest of the targets, i.e., digit 10, were presented softly (soft 10) along with the other digits and the subjects were required to respond to all of them (soft 10 and the other digits) with a tap. The digits were recorded on an audio cassette at the rate of one per second. The test retest reliability correlation was found to be 0.69 with adequate discriminant validity (Rana & Rao, 2013). The final score was the total of omissions and commissions.

Go/No-go Test (Devender Kumar, 2000)

This test was developed as a part of standardizing an assessment battery for neuropsychological tests. In this task, two equiprobable stimuli (names Ram and Mohan) were presented to the subject in random order and subjects were asked to respond to one stimulus only and to withhold their response to the other stimulus. There were 50 repetitions of ‘Ram’ and 50 repetitions of ‘Mohan’. They were presented randomly at the rate of one stimulus per second by an audiocassette player. The subjects were instructed to respond with a tap only to the name ‘Mohan’. The test retest reliability correlation was 0.62 for this test and it was found to have adequate discriminant validity by being able to differentiate between patients with frontal lobe lesions and normals. The score was obtained by the total errors of omissions and commissions (Rana & Rao, 2013).

Procedure:

60 normal people as per the inclusion and exclusion criteria were selected as subjects. An informed consent was obtained from them after explaining about the study. The subjects were seated comfortably in a quiet room and the tests were administered. The four tests were given in the same session with intervals of a few minutes between the tests. Effects of any fatigue was not observed in subjects. The order of presentation was randomized across subjects.

Statistical analysis

The results obtained were tabulated and analyzed on SPSS 17.0. Descriptive statistics of mean and standard deviations were used as measures of central tendencies and distribution.

Pearson's correlation (r) was used to explore the relationship between the tests. The scores in each test were correlated with the scores on the other tests. A 'p' value < 0.05 was considered as a significant correlation.

Results

The sample consisted of 30 males and 30 females, who had finished school education and were between the ages of 16 and 30 years. The mean age of the sample was 21.07 years with a standard deviation of 4.95 and the mean of education was 8.42 years with a standard deviation of 2.61.

The results of the correlation analysis for different tests are given in Table 1. The time score of the attention test, Figural Visual Scanning test had a significant and positive correlation with Figural Visual Scanning errors, Stop Signal Scores and Go/ No Go scores. This indicated that the subjects who took more time on Figural Visual Scanning Task also made more mistakes on the same task, and also on both tests of inhibition. However, it did not correlate with any of the scores on the other test of attention, i.e., Auditory Target Detection test. Figural Visual Scanning errors had positive correlation with Stop Signal Scores and Go/ No go scores. This indicated that those who had more errors on Figural Visual Scanning test also performed poorly on tests of inhibition. Auditory Target Detection Test hits had a significant and negative correlation and misses had a significant, positive correlation with Go/ no go scores. This indicated that Auditory Target Detection test showed a significant association with Go/no go test only. Stop Signal Scores and Go/ no go scores showed a significant, positive correlation. This indicated that the two tests of inhibition were positively associated.

Discussion

The results (in Table 1) showed that that the two tests of attention did not correlate with each other. The Figural Visual Scanning Test is a test of visuospatial attention and involves the parieto occipital areas of the brain (Blankenburg et al, 2010) whereas Auditory Target Detection Test is a test of auditory attention and involves the auditory cortex in the temporal lobe of the brain (Jemel, Oades, Oknina, Achenbach & Ropcke, 2003). The Figural Visual Scanning Test had different targets. In each trial, the distracters were similar to the targets. Therefore, the test must have focused attention. On the other hand, Auditory Target Detection Test may involve sustained attention. In this test, the target was presented repeatedly. The two tests may not have correlated as they could be measuring different aspects of attention, and were mediated by different brain areas.

From the correlational analysis, which was carried out, it was found that there was a significant association between Stop Signal Test and Go/No Test (Table 1). The two tests measured the same process, i.e., inhibition of

Table 1: Correlation between test variables

	FVS Time	FVS error	ATDT Hit	ATDT Miss	ATDT Commissions	SS
FVS Time						
FVS error	.634**					
ATDT Hit	.046	-.175				
ATDT Miss	-0.46	.175	-1.00**			
ATDT Commissions	.102	.044	-.140	.140		
SS	.448**	.431**	-.127	.127	.046	
GNG	.255*	.495**	-.363**	.363**	.237	.597**

*: Correlation significant at .05 level. ** Correlation significant at .01 level.

FVS: Figural Visual Scanning; ATDT: Auditory Target Detection Test; SS: Stop Signal; GNG: Go no go motor responses, which are mediated by the same areas in the brain, i.e. the orbito frontal area and basal ganglia of the brain (Band & Boxtel, 1999). The nature of the stimulus was auditory in both tests and both tasks required a motor response. Therefore, the similarity between the two tests in terms of the stimuli, the responses and the brain areas mediating the processes, could be the reasons for the high correlation.

The relationship between attention and inhibition was measured by correlating the measures obtained on attention and inhibition tests. Results indicate that the Figural Visual Scanning Test correlated significantly with both tests of inhibition. Auditory Target Detection Test correlated significantly with only Go/No go Test. Thus, there is a difference in the nature of correlation between attention and inhibition, when attention is measured by Figural Visual Scanning Test and Auditory Target Detection Test. The Figural Visual Scanning Test included active processing of information, which utilized inhibitional processes also. In this test, the distracting stimuli were perceptually similar to the target. The perceptual similarity between the targets and distracters result in a higher difficulty level in identifying the target. The difficulty arises because the response required by the target is also evoked by the distractor. In order to perform the task accurately, inhibition of the response to the distractor is required. Therefore, in the Figural Visual Scanning Test, attentional processes are activated in identifying the target and inhibitional processes are activated in suppressing the responses to the distracters. It is seen that inhibition is involved in focused attention tasks rather than sustained attention tasks (Bitsios & Giakoumaki, 2005).

In the Go/No go Tests, the targets and the distracters were similar throughout the test. In the Auditory Target Detection Test, even though the distracters were different, the target was the same. Hence, it can be hypothesized that both these tests required sustained attention to respond to only one kind of stimulus. They utilized more attentional processes in terms of vigilance. Since, both the tests required sustained attention there is a positive correlation between them. On the other hand, the Stop Signal Test required more active inhibition of responses, as the distracters were similar to the targets. Inhibition of the responses to the targets was needed for successful performance. The Stop Signal Test and the Auditory Target Detection Test required different functions. The Stop Signal Test required more inhibitional processes and the Auditory Target Detection Test required more attentional processes, and hence the lack of correlation.

Researchers and clinicians have the tendency to describe attention and inhibition independently and devise experiments that measure these functions separately. On the other hand, many researchers approach them as similar functions. Inhibition can occur only when the attentional processes are intact and vice versa. Both involve simultaneous presentation of targets and distracters. Moreover, there is an involvement of the same brain areas, i.e., the frontal cortex, in both the processes (Araki et al, 2005). Only a careful analysis of the various factors involved would result in adequate interpretation of the findings, as these two functions are closely linked.

Overall it is seen that the processes of attention and inhibition are positively associated, and hence cannot be considered as independent functions. In a similar study conducted by Pasquali (2013), it was found that tests of attention and inhibition correlated significantly and these patterns of interrelationships suggested that as the ability to pay attention increased, disinhibitory behaviour decreased. The author noted that these constructs, which are overlapping, its divergent validity cannot be supported. However, the modality i.e., whether visual or auditory and the dimension of attention measured is either focused or has sustained influence measures the association between them. The most prominent difference between the two functions is the multidimensionality of attention, as opposed to the unidimensionality of behavioural inhibition. Attention has several aspects, which include selection, sustenance and division, and inhibition is similar to the selection aspect of attention. The researchers who hypothesize that attention and inhibition are two sides of the same coin focus predominantly on selective attention or selective responding (Miller & Cohen, 2001; Mostofsky & Simmonds, 2008) and base their models on the ‘Biased competition model' by Desimone and Duncan (1995). In our findings also, we find that the test, Figural Visual Scanning Test for focused selective attention correlated with the tests of inhibition while the test of sustained attention, Auditory Target Detection Test did not. This points towards the fact that during assessment, the multiple dimensions of attention needs to be examined to arrive at a comprehensive assessment of attention, whereas only assessing focused attention will yield results, which are very similar to inhibition.

Limitations of Study:

The sample size of the study was small, however, efforts were made to control the effects of age and gender and education by narrowing the age and education distribution and having an equal number of participants from each gender group. It would have been useful to have an age, gender and education matched patient group with impairment in each of the aspects of attention and compare them with the results of tests of inhibition to give more conclusive results. Further, only two tests of attention and two tests of inhibition were selected for comparison. However many other tests of attention which measure the different aspects of attention need to be compared with other tests of inhibition that are available and their relationship needs to be explored further.

Implications and suggestions

The study demonstrated a significant association between tests of attention and inhibition. In clinical testing, it should be noted that these are not independent constructs that can be defined or reported as exclusive. Impairment in tests of inhibition should be carefully examined in relation to attentional problems and vice versa to draw clinically relevant conclusions and to exclude the other. For example, for a child with Attention Deficit Hyperactivity Disorder, it would be useful to administer tests that assess different aspects of attention, rather than a test of focused attention or behavioural inhibition to examine whether any other aspects of attention is preserved to understand more regarding any strengths that are present that can be used for cognitive retraining purposes. Future studies should include a variety of tests of attention and inhibition and examine the subcomponents. Neuroimaging studies of attention and inhibition will further help to arrive at better conclusions regarding the brain areas that are related to these functions.

Conclusion

The present study found that there is a significant association between the two processes of attention and inhibition. Since they are related, a deficit in one process can influence the other. They appear like two sides of the same coin, and only careful analysis of the different dimensions will give a comprehensive assessment of the independent factors involved in attention. However, they comprise of two systems and the results of tests depend on a variety of factors involved, which include the modality of testing and the type of stimuli presented, the type of response and difficulty of the task. Interpretation of test results should include a careful analysis of all these factors before drawing conclusions about the function that was assessed.

References

Araki, T., Kasai, K., Nakagome, K., Fukuda, M., Itoh, K., Koshida, I., Kato. N. & Iwanami, A. (2005). Brain electric activity for active inhibition of auditory irrelevant information. *Neuroscience Letters, 374* (1), 11-16.

Aron, A.R. (2007). The neural basis of inhibition in cognitive control. *The Neuroscientist, 13*(3), 214-228.

Band, G.P.H., & Boxtel, G.J.M. (1999). Inhibitory motor control in stop paradigms: Review and interpretation of neural mechanisms. *Acta Psychologica, 101,* 179-211.

Barkley, R. (1997) Behavioral Inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121,* 65-94.

Bitsios, P., & Giakoumaki, S.G. (2005). Relationship of prepulse inhibition of the startle reflex to attentional and executive mechanisms in man. *International Journal of Psychophysiology, 55,* 229-241.

Blankenburg, F., Ruff, C.C., Bestman, S., Bjoertomt, O., Josephs, O., Deichmeann, R., & Driver J. (2010). Studying the role of human parietal cortex in visuospatial attention with concurrent TMS-MRI. Cereb Cortex, 20(11), 11-ski, C., Prvulovic, D., Goebel, R., Zanella, F.E., & Linden, D.E. (2004). Attentional systems in target and distractor processing: a combined ERP and fMRI study. *Neuroimage, 22*(2), 530-540.

Daffner, K.R., Mesulam, M.M., Scinto, L.F., Acar, D., Calvo, V., Faust, R., Chabrerie, A., Kennedy, B., & Holocomb, P. (2000). The central role of prefrontal cortex in directing attention to novel events. *Brain, 123*, 39-927.

De Ruiter, M.B., Kok, A., & Schoot, V.M. (1998). Effects of inter and intra modal attention to non-spatial visual stimuli: an event related potential analysis. *Biological Psychology, 49*(3), 94-269.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*, 193-222.

Devender, K. (2000). Development and standardization of tests for the measurement of inhibition. (Unpublished M.Phil Dissertation), *National Institute of Mental Health and Neurosciences,* Bangalore, India.

Dimitrov, M., Nakic, M., Elpern-Waxman, J., Granetz, J., O'Grady, J., Phipps, M., Grafman, J. (2003). Inhibitory attentional control in patients with frontal lobe damage. *Brain and Cognition, 52*(2), 258–270.

Gopukumar, K. & Rao, S.L. (2005). *Six month follow up study of neuropsychological changes in neurologically asymptomatic seropositive HIV infected subjects from South India.* Paper presented at international symposium on HIV infection and the central nervous system, Rome, Italy.

Gupta, J. D., Rao, S., Satishchandra, P., Gopukumar, K., Wilkie, F., Waldrop-Valverde, D., Kumar, M. (2007). Neuropsychological deficits in human immunodeficiency virus type 1 clade C–seropositive adults from South India. *Journal of NeuroVirology, 13,* 195-202.

Jemel, B., Oades, R.D., Oknina, L., Achenbach, C. & Ropcke, B. (2003). Frontal and temporal lobe sources for a marker of cintrolles auditory attention: the negative difference (Nd) event-related potential. *Brain Topogr, 15*(4), 62-249.

Kok, A. (1999). Varieties of Inhibition: Manifestations in cognition, event related potentials and aging. *Acta Psychologia, 101,* 129-158.

Menon, V., Adleman, N.E., White, C.D., Glover, G.H. &, Reiss, A.L. (2001). Error-related brain activation during a Go/NoGo response inhibition task. *Hum Brain Mapp, 12*(3), 131-143.

Miller, E.K., & Cohen, J.D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24,* 167–202.

Mostofsky, S.H. & Simmonds, D.J. (2008). Response inhibition and response selection: two sides of the same coin. *Journal of Cognitive Neuroscience, 20*(5), 61-751.

Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*, 97-113.

Rana, D.K. & Rao, S.L. (2013). Development and Standardization of Tests for the Measurement of Inhibition. *Delhi Psychiatry Journal, 16*(1), 90-97.

Roberts, A.C. & Wallis, J.D. (2000). Inhibitory control and affective processing in the prefrontal cortex: neuropsychological studies in the common marmoset. *Cerebral Cortex, 10*(3), 252-262.

Rubia, K., Russell, T., Overmeyer, S., Brammer, M.J., Bullmore, E.T., Sharma, T., Taylor, E. (2001). Mapping motor inhibition: conjunctive brain activations across different versions of go/no-go and stop tasks. *Neuroimage, 3*(2), 250-261.

Thomas, S. (2005). *Standardization of tests of attention and inhibition.* (Unpublished M.Phil Dissertation), National Institute of Mental Health and Neurosciences, Bangalore, India.

Vecera, S.P. & Rizzo, M. (2004). Attention: Normal and disordered Process. In M. Rizzo & P.J. Eslinger. (Eds) *Principles and Practice of Behavioural Neurology and Neuropsychology*. Pennsylvania: Saunders and Co.

Wilkie, F. L., Goodkin, K., Ardila, A., Concha, M., Lee, D., Lecusay, R., O'Mellan, S. (2004). HUMANS: An English and Spanish Neuropsychological Test Battery for Assessing HIV-1-Infected Individuals—Initial Report. *Applied Neuropsychology, 11*(3), 121-133.

Wilkie, F.L., Eisdorfer, C., Morgan, R., Loewenstein, D.A., & Szapocznik, J. (1990). Cognition in Early Human Immunodeficiency Virus Infection. *Archives of Neurology, 47*, 433-440.

Manuscript submitted on February 2, 2016
Final revision received on April 9, 2016
Accepted on April 12, 2016.

Susan Thomas, Lecturer, Division of Mental Health and Neurosciences, St. John's Research Institute, Bangalore-560034, India. Email: susansusmi@gmail.com.

Shobini L. Rao, Retired Professor, Department of Clinical Psychology, National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore- 560029, India.

B. Indira Devi, Professor, Department of Neurosurgery, National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore- 560029, India.