Visual spatial search task (VISSTA): a computerized assessment and training program

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ABSTRACT

The aim of this paper is twofold 1) to introduce a computerized platform of Visual Spatial Search Task (VISSTA), its current package and potential for a variety of additional programs, and 2) to present results of the basic package of stroke patients and healthy controls. *Method*. Participants included 39 healthy individuals; 25 patients post right hemisphere damage (RHD) with unilateral spatial neglect (USN); 27 patients post RHD without USN; and 20 patients post left hemisphere damage (LHD). All participants were tested on the computerized VISSTA and paper and pencil cancellation tests. The stroke patients were also tested on the ADL checklist and FIM. *Results*. Findings indicate that the VISSTA is a valid visual search assessment that significantly differentiated between patients following stroke and healthy controls and between different stroke patient groups. USN patients showed impairment in both visual search conditions and clear laterality bias when target was presented on the left side of a computer screen, this was true for success rate and reaction time. RHD patients without USN performed better than those with USN, however, they still show impairment in attention properties of visual search and detection of targets (both on left and right) compared to healthy individuals. *Conclusions*. The VISSTA tool was found to be sensitive to levels of visual spatial attention by means of accuracy and reaction time. Results suggest that it is important to supplement the conventional paper and pencil tests and behavioral measures with tools that provide both accuracy and RT parameters in a randomized and more complex fashion. The VISSTA is also suitable for treatment as it provides a flexible platform.

1. INTRODUCTION

Attention is defined as a cognitive mechanism that enables people to process relevant external stimuli, internal thoughts or actions while ignoring irrelevant ones (distracters). Visual spatial attention is considered the attentional mechanism that assists us in scanning the environment for relevant stimuli. Theoretical explanations of visual spatial attention mechanisms attempt to determine whether detecting a visual object occurs by simultaneously analyzing all the objects in the visual field (termed also as parallel, pop-out, or feature search), a task which requires minimal ('spread attention') or no attentional efforts, or whether visual-detection task requires successive analysis of each object (termed also as serial or conjunction search), necessitating attention shifting and selection efforts (Nakayama and Joseph, 2000; Pavlovskaya et al, 2002; Treisman and Gelade, 1980; Treismann, 1988; Treisman, 1999).

Impairments in visual search can immerge following brain damage, either due to impaired spatial attention mechanisms like in the complex neurological disorders of Unilateral Spatial Neglect (USN), or field cut deficits such as hemianopsia. Visual spatial deficits affect the ability to function in many aspects of daily living and have serious consequences for rehabilitation and long term functional capacity (Heilman et al, 1993; Kalra et al, 1997; Katz et al, 1999), for this reason it is essential to assess and treat these disorders in the rehabilitation process.

Assessment of visual spatial deficits (including USN) is usually performed using paper and pencil tests. Various cancellation tasks are employed where patients are asked to search for a specific target amongst varied number of distracters (Weintraub & Mesulam, 1987). The conventional tests have some limitations,

usually the tasks do not change from one evaluation to another and have only one level of difficultly that may lead to a ceiling effect, in addition, reaction time, which is an important component of visual spatial attention, is not provided. Moreover there is a need to provide clinicians with user friendly training tools in order to improve their patients' visual search abilities in a controlled, gradable way. There are conflicting results with regards to the performance of patients post stroke in the two levels of visual search (feature versus conjunction). Some studies show that patients with USN have difficulties detecting targets in the contralesional side with significantly slower reaction time (RT) at both levels, while some claim that the main difficulty is in the more complex serial search (Behrmann et al, 2004).

The VISSTA, computerized platform, was developed to serve both assessment and training of visual spatial attention deficits. VISSTA is based on Sun Micro System's Java platform. It requires initial installation of Java's virtual machine (which is freely available). After this one time installation, it can be easily used by launching the application. VISSTA manages a database of the patients and the sessions. This detailed database enables retrieval of information and report generation. The reports can be generated according to the user's preferences (level of details, output format etc.) and either be printed or saved. The system also enables access to the raw data for further analysis. At the heart of VISSTA's operation stands the loop of presenting a stimuli (a screen) and accepting the patients input (while measuring its time and correctness).

To facilitate a variety of different type of stimuli VISSTA has a powerful feature called packages. Packages are easy to distribute files that contain the full media (images) and definitions (grouping, desired response, durations etc.) that are required to run a session. VISSTA can easily edit, create and read packages, hence supporting a quick, simple and easy enhancement of the available content. The base package was developed based on Treisman and Gelade feature theory, which is comprised of two main conditions; feature and conjunction search, 108 screens are randomly arranged with variations of location of target, number of distracters, side of the screen etc. and approximately 20% of the screens are without target (only distracters).

The newly developed computerized visual search test and training program VISSTA (Visual Spatial Search Task), presented in this paper, applies both 'feature' and 'conjunction' search principles to assess identification rate and reaction time (RT) in the two conditions. The aims of this paper are to report the psychometric properties of the VISSTA and to discuss the advantages of using computerized search tasks, both feature and conjunction based, in the assessment of USN.

2. METHODS

2.1 Participants

Healthy participants (N=100), ages 25-90 years old, independent in activities of daily living (ADL), were recruited from the community and tested for standards on VISSTA. Thirty nine of them were selected from the pool to match the patients' age group (mean age = 63.5, SD=13.6). Participants post stroke were recruited from Lowenstein rehabilitation center and than allocated to three groups: a) 25 patients with right hemisphere damage (RHD) with unilateral spatial neglect (RHD +USN); b) 27 patients with right hemisphere damage (RHD) without unilateral spatial neglect (RHD – USN); and c) 20 patients with left hemisphere damage (LHD) without USN. Patients with visual field deficit were excluded from the study. All patients were 3-12 weeks post their stroke event.

2.2 Instruments

2.2.1 Measures to determine USN. Within the RHD patients the diagnosis of USN was determined based on deficits in the following measures: Behavioral Inattention Test (BIT) (Wilson et al, 1987), a widely used battery of tests for assessing spatial deficits and screening for USN; The Mesulam and Weintraub random symbol cancellation task (MWCT) (Weintraub, 2000); Catherine Bergego Scale (ADL checklist) (Azouvi, 2003) a report of an experienced occupational therapist concerning USN behavior during basic ADL activities; and the Functional Independence Measure-FIM (Granger et al, 1993) is used to measure the degree of disability and burden of care in everyday activities.

2.2.2 The computerized visual search task (VISSTA). The program includes two conditions, feature and conjunction. Feature visual search: subjects were asked to detect a visual target (red circle) located amongst several peripheral distracters on a computer screen. The target differed from the distracters by color (e.g., a red circle among blue circles). The target appeared randomly in one of 20 predetermined locations (5 targets on each quarters of the screen: right / left; up / down) and 5 screens without targets. The distracters appeared randomly on both sides of the screen. The location of target and the set-size of distracters varied (from 3

distracters to 23). Thirty percent of the screens were without target (presenting only distracters and termed 'catch trials'), overall there are 108 screens that the participants has to respond to. The subjects were required to press one button as soon as the target was detected and another button if no target was detected. Each screen appeared for 3000 msec regardless of participant's response. Reaction time and success rates were measured. Conjunction visual search: Subjects were asked to detect the same visual target (red circle), however this time, among two types of distracters (blue circles and red squares), the target differed from the distracters by at least one primary feature (e.g., color or shape) but was similar on the other feature. The location of target and the distracters protocol were the same as for the 'feature' condition. The exposure time was 4500 msec based on a preliminary trial made with healthy elderly and patients post stroke. See Figure 1 for an illustration of one screen.

For training purposes the parameters of the program can be changed and graded, namely the exposure time, the number of screens, the stimuli etc. The output provides detailed data on rates of success and omissions, divided by quadrants and response time.

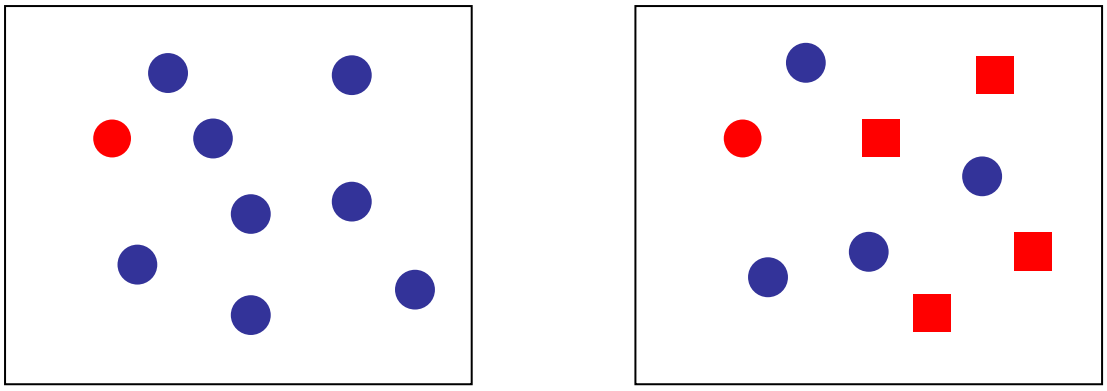

Figure 1: *Feature and conjunction search.*

2.3 Procedure

Patients first went through the paper-and-pencil tests to determine the presence of USN. Patients were allocated to one of three groups according to hemisphere lesion side and the evidence of USN. The participants were seated in front of the monitor (size 17inch) at their arm length distance. All the participants (healthy and patients) went through training on the computerized tests to make sure they understood the instructions and were capable of performing the two tasks. The computerized visual search assessment was conducted in one session with a short break between the two tasks. The feature condition was preformed first and than the more complex conjunction condition. For the patients the response buttons were placed in front of the subjects in a position that was comfortable and enabled them to press the two buttons without looking down. Healthy subjects used the keyboard. The FIM and ADL checklist were completed by the treating therapists. The research study received the Institutional Review Board (IRB), Human Rights Committee approval and all participants signed a consent form before entering the study.

3. RESULTS

3.1 Visual search computerized tasks: comparison between and within groups.

The data was analyzed using One Way ANOVA and coefficient contrasts tests to compare the groups in respect to each condition, feature and conjunction. The analysis was conducted separately for the responses made to targets on left and right visual fields and where no target was presented (catch trials). All ANOVA results between groups were significant at p=.026-.0001 (see Tables 1 and 2). Results for each condition with coefficient contrasts show that RHD +USN patients preformed significantly worse than the other groups in all conditions except for the feature condition when targets were presented in the right visual field.

3.2 Feature versus conjunction.

In all four groups RT was longer for the 'conjunction' compared to the 'feature' condition (RHD+USN: z = 3.7, p = .007; RHD-USN: z = 4.5, p = .000; LHD: z = 3.8, p= .001; Healthy: z = 5.4, p = .000; (see Table 2). In RHD groups, with and without USN, patients' success rate was higher for 'feature' condition than

'conjunction' (RHD+USN: z = 3.1, p = .002; RHD-USN: z = 2.4, p = .015). In the LHD group a significant difference was detected in the conjunction condition such that the RT for right targets was longer than RT to left targets (z = 2.3, p = .02). Both comparisons between and within groups are demonstrated in Figures 2 and 3.

Table 1: *Hit rate (%) in feature and conjunction search; One way ANOVA between groups.*

Group		**Feature**	
	Target Left	Target Right	Catch Trials
Healthy	97.9 (.03)	95.9 (.06)	97.5 (.06)
LHD	90.2 (.21)	86.9 (.19)	86.4 (.22)
RHD-USN	83.2 (.24)	88.6 (.15)	82.8 (.24)
RHD+USN	52.9 (.33)	85.8 (.15)	72.0 (.23)
F (p)	23.2 (.000)	3.7 (.014)	9.7 (.000)
		Conjunction	
	Target Left	Target Right	Catch Trials
Healthy	92.6 (.1)	92.3 (.11)	92.2 (.12)
LHD	93.7 (.07)	94.4 (.06)	92.8 (.09)
RHD-USN	85.5 (.13)	88.9 (.13)	80.4 (.22)
RHD+USN	40.9 (.27)	76.8 (.18)	67 (.19)
F (p)	61.7 (.0001)	9.6 (.0001)	14.3 (.0001)

Table 2: *Reaction time (msec) in feature and conjunction search; One way ANOVA between groups.*

Group		**Feature**	
	Target Left	Target Right	Catch Trials
Healthy	940.3 (451.4)	983.7 (419.7)	1122.8 (420.8)
LHD	1090.5 (295)	1188.7 (282.9)	1515.6 (580.4)
RHD-USN	1378.3 (977.4)	1224.9 (444.5)	1478.8 (419.8)
RHD+USN	2522.8 (1261)	1421.1 (912.6)	1806.3 (682.1)
F (p)	20.5 (.0001)	3.2 (.026)	9.2 (.0001)
		Conjunction	
	Target Left	Target Right	Catch Trials
Healthy	1455.1 (616.7)	1589.8 (645.9)	2028 (506.9)
LHD	1697.3 (447.5)	1919.2 (522.9)	2643.6 (483.2)
RHD-USN	2024 (706.6)	1910.2 (699.5)	2537.8 (697.9)
RHD+USN	3701.9 (1000.1)	2255.6 (906.3)	2935.8 (1223)
F (p)	53.5 (.0001)	4.6 (.005)	7.8 (.0001)

RHD/LHD = Right- / Left-hemisphere damage; USN+/- = Patients with/without unilateral spatial neglect. Catch trials = Trials where no target was presented.

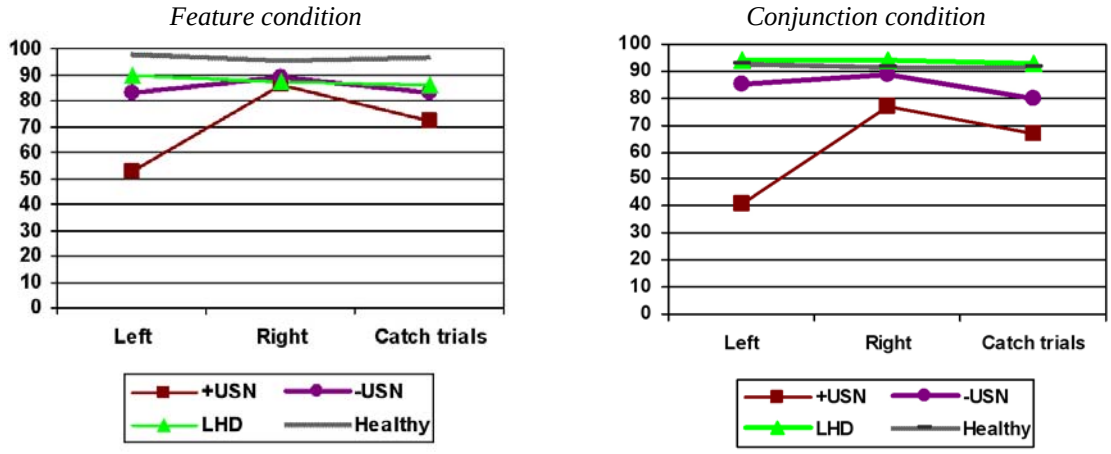

Figure 2: *Hit Rate (percent success) in Feature and Conjunction.*

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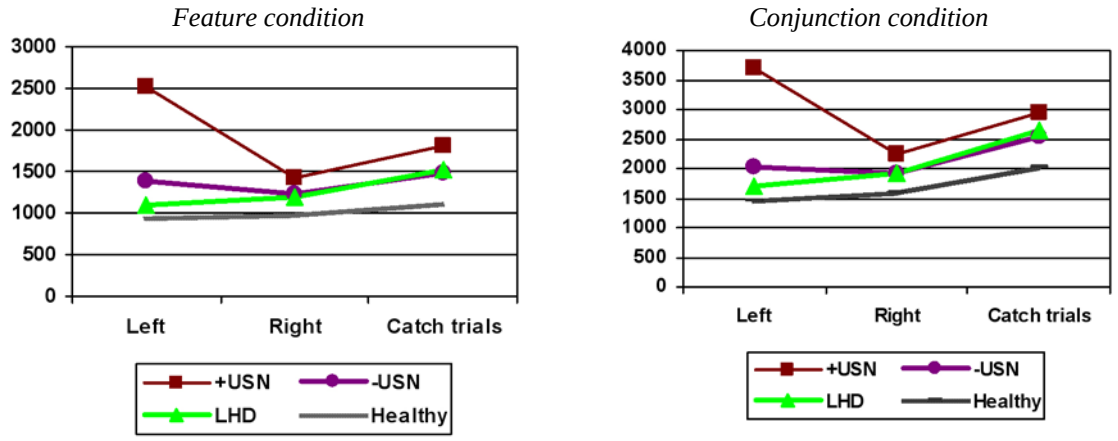

Figure 3: *Reaction Time in Feature and Conjunction.*

3.3. Correlations between the visual search conditions and USN measures

Spearman rho correlations between VISSTA and USN paper and pencil measures show moderate significant correlations at $p < .001$ both in the 'feature' and 'conjunction' conditions. In the RHD+USN (feature $r = .62$; conjunction $r = .57$), healthy (feature- $r = .49$; conjunction- $r = .46$) and LHD (feature- $r = -.56$; conjunction $r = .66$) groups, no significant correlations were found in the RHD-USN. Correlations with the ADL checklist (that was relevant only to the USN patients) revealed the same trend for the RHD+USN group (feature- $r = -.71$, $p<.001$; conjunction $r = -.51$, $p < .005$) indicating that higher score of USN in activities of daily living (meaning more disability) correlated with lower success rate in visual search. Correlations between the FIM measure and the total success rate in each visual search condition show significant moderate correlations in the RHD+USN group for both conditions (feature- $r = .46$, $p < .005$; conjunction $r = .65$, $p < .001$).

4. CONCLUSIONS

The computerized VISSTA program is based on a visual search theory differentiating between levels of visual attention – simple feature search versus a more complex attentional driven conjunction search. Findings indicate that the VISSTA is a valid visual search assessment that significantly differentiated between patients following stroke and healthy controls and within stroke patients groups. VISSTA scores were moderately correlated with the paper and pencil and ADL tests in both feature and conjunction conditions. The computerized version provides additional information on visual search abilities and attention by measuring the reaction time in addition to successful detection of stimuli. The VISSTA program provides additional important parameters for assessing and treating visual spatial attention such as limiting the exposure time of the stimuli presentation as well as providing repeated presentation of randomized stimuli over relative long periods of time (5.5-8 minutes) which challenges sustained attention capabilities.

The conventional paper and pencil tests have some limitations compared to a computerized version. Usually the tasks in the paper and pencil tests do not change from one evaluation to another and have only one level of difficultly that may lead to a ceiling effect, while in a dynamic platform, such as a computerized tool, it is possible to change the stimulus, its background and its exposure time thus increasing complexity and sensitivity. In addition, the measurement of reaction time provides important information on spatial attention which is not provided by the conventional tests (Deouell, 2005). The computerized test seems to provide valid and sensitive information that can be useful for the therapist to assess severity of visual spatial deficits and detect even subtle changes in visual attention prior to further evaluation.

In conclusion, the VISSTA tool was found to be sensitive to levels of visual spatial attention by means of accuracy and reaction time. Results suggest that it is important to supplement the conventional paper and pencil tests and behavioral measures with tools that provide both accuracy and RT parameters in a randomized and more complex fashion. The computerized visual search tool can serve as a sensitive measure for the presence of visual spatial deficits (and general decreased attention) at various levels in the rehabilitation process in addition to paper and pencil and functional tests.

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