Using technology and tangible interfaces in a visuospatial cognition task: the case of the Baking Tray Task

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Abstract. The Baking Tray Task (BTT) is a neuropsychological test, aimed to assess unilateral spatial neglect (USN), a visuospatial disorder mainly associated to right parietal lobe damage. Over the years, the BTT has been re-proposed in different forms, other materials to be placed and in both digital and virtual environment preserving the initial settings and the way of administration. In this paper, we present two versions of BTT, the E-BTT and the BTT-SCAN, improved by technology.
The aim of these tools is to present a new technological version of the same test in order to preserve a high validity and reliability and to acquire massive and more precise data.

Keywords: Visuospatial Cognition · Assessment · Neuropsychology · Baking Tray Task · Tangible Interfaces

1 Introduction

Spatial cognition is the ability in all species to visually perceive the locations of stimuli in the space in order to navigate in the surrounding environment [14]. In particular, visuospatial abilities allow to identify visual and spatial relations among objects in terms of spatial coordinates. Whenever the spatial cognition is impaired, the execution of daily activities is compromised for the people and an accurate evaluation and assessment of visuospatial abilities becomes of fundamental importance [10]. Neuropsychological assessment is a performance-based procedure used to assess various cognitive functions such as memory, attention, reasoning, judgment, problem-solving, visuospatial skills and language. Generally, neuropsychological assessment (e.g. the Hopkins Verbal Learning Battery or the Brief Visuospatial Memory Test[23])is performed with a battery approach to evaluate cognitive ability areas. The major part of neuropsychological tests are administered in traditional *paper-and-pencil tests*, particularly long and boring to perform.

For this reason, we can use the evaluation of cognitive functions mediated by technology to overcome some consequences of neuropsychological assessment. For example, computerized tests can be performed in a shorter time ensuring a high validity and reliability thanks to precision, standardization and objectivity of the test[15]. Moreover, the computerized assessment of cognitive functions can also minimize the ceiling effect (when the performance of the individuals is maximized in low difficult tasks) and the floor effect (if the task is so difficult that no one is able to perform it) [27]. In the next section, after a brief description of a test adopted for the diagnose of spatial impairments, will be described two versions of the same task that exploit the advantages derived by technology.

2 The Baking Tray Task (BTT)

In neuropsychology, the assessment of spatial cognition can be performed through plenty of tasks, as described by Cerrato and colleagues [7].One example is represented by The Baking tray task (BTT), a relatively recent test developed by Tham and Tegner [26] for assessing Unilateral Spatial Neglect (USN), a visuospatial disorder mainly associated to right parietal lobe damage, in which the patients show unawareness of the stimuli on the left side of their visual field. This disorder cannot be considered a sensory (visual, acoustic and / or tactile) deficit, indeed, these patients ignore what is placed in the controlesional space due to an inability to orient attention and to explore space [2].
The subjects are instructed to spread, as evenly as possible, 16 cubes over a 75 x 100 cm board, as if they were buns/cookies on a baking tray. The 16 cubes have a dimension of 3.5 cm and they are placed in a box directly in front of the subject. There is no time limit to finish the task and each cube have to be dispose over the board. A not uniform placement of the cubes, with a number of cubes in half of the board lower than 6 or greater than 10, could be a sign of USN. The BTT is an ecological, sensitive and easy test and it detects moderately severe Spatial Neglect compared to common tests for neglect, including the barrage test [1] and the line bisection test [25]. Furthermore, BTT requires less effort and attention than cancellation tasks, because the number of distractors and the ability of the patients to distinguish them from the target may negatively influence the performance [20]. In addition, the Cancellation Tasks are influenced by practice because the patients seem to memorize the sequence of steps, while, the Baking Tray Task is insensitive to practice and set effect, there are no right or wrong solutions and its execution is complicated to memorize despite exercise [26].
Over the years, the BTT has been re-proposed in different forms, other materials to be placed and in both digital and virtual environment, while preserving the initial settings and the way of administration. In recent years, thanks to the support of technology, we have developed two enhanced versions of the BTT that are described in the next subsections.

2.1 E-BTT

In 2017 [5], Cerrato and Ponticorvo have realized a version of the Baking Tray Task, named E-BTT that has been developed following the principles of *Gamification* [3]. The E-BTT is a technology-enhanced version of BTT, reproduced in a virtual environment by STELT software [16] (Smart Technologies to Enhance Learning and Teaching) that allows to create prototypes and augmented reality environments based on Articial Intelligence methodology (Agents Based Modelling) and tangible interfaces (physical objects that can be manipulated). So, there is a parallel and integrative use between smart technologies and physical objects, allowing manipulative intervention by the user on the reality and the interaction between the user and the computer, promoting multisensoriality [18]. It mainly consists in three parts/modules: *Storyboarding*, is the presentation of personalized scenarios useful to provide the test instructions to participants. In the E-BTT, the scenario is the design of a baker, who knead bread. *Recording*, is to track all users data interaction and, finally, and *Adaptive Tutoring*, by which the user receives on-time intelligent feedbacks from a virtual tutor. An important aspect of the tutoring system lies on the possibility to adapt the task on the user's level [19, 17]. In order to perform the task, the user had to help Louis, a cartoon baker, trying to dispose 16 small buns on the tablet surface, as evenly as possible. The main advantage of this instrument is to diagnose spatial neglect and other disorders related to visuospatial abilities, stimulating the participation and involvement of users in the interaction with the computer through STELT software.

A further development of the E-BTT is represented by the integration of an Articial Vision module, supported by a camera, able to scan and recognize the cubes' disposition. Its functioning will be described in the next subsection.

2.2 BTT-SCAN

The BTT-SCAN is an ecological and technology enhanced tool to assess visual neglect, developed by Cerrato et colleagues [6, 8].

During the administration of BTT-SCAN, the 16 cubes have to be arranged on a surface of 48 cm x 34 cm (a tray dimension smaller compared to the one adopted by Tham and Tegner).

Initially, we adopted 16 cubes of 3.5 cm and different colors (4 red, 4 orange, 4 green and 4 blue). The cubes are automatically detected by a camera connected to a PC through ArUco Markers [13], a kind of tags very popular in augmented reality technology [9, 22, 21], that allow the recognition and the acquisition of their spatial position (as X and Y coordinates). The ArUco Markers are sticked on the cubes, in order to be detected, and on the corners of the board to frame the limits of the *baking tray*. The BTT-SCAN also includes a software that digitally recreates the cubes' disposition on the screen of the PC. The instructions are the same of original study: subjects are asked to spread out 16 cubes on a board, as if they were buns on a baking tray. At the end of the test, the BTT-SCAN saves the information related to the subjects performance in an

Fig. 1. A typical configuration at the BTT-SCAN

Excel file, stored in the software database for later review. The instructions, for exporting data, are written in English on the left; in addition, BTT-SCAN, for each experimental session, reports the following data: the name and age of the participants, the date of the session, the start and finish time, the field height and the field width in pixels, the test duration expressed in seconds, the cubes on the right, the Left-Right subtraction of the cubes' disposition, the type of distribution and the BTT bias (in percentage). This last measure is given by the formula 100*(right-left)/(right+centre+left) and has been developed by Facchin [11] in order to calculate the lateralization index showed by participants during the BTT: if it is negative, the configuration is mainly on the left, if it is positive, the configuration is mainly on the right, if it is to 0, the configuration is optimal. BTT-SCAN automatizes the scoring of the performance, produces automatically and instantaneously the diagnosis and several indexes of patients performance and helps clinicians in data collection and supervision. These data proved to be useful for investigating some aspects related to spatial cognition of people, highlighting, for example, the preferred starting and ending point of the cubes configuration, and what kind of constructional strategy people adopt, with the aim to reveal the preferred patterns showed by participants. This enhanced version of the BTT presented some instability in collecting the data (for example due to the processing of the shadows on the surface) and required improvements in reliability, validity and robustness that are described in the next section.

3 Future directions and Conclusions

The aim of this paper has been to present the evolution of the BTT, from the original version to the recent technologically advanced versions developed by our research group, to show the advantages derived by technology. In the E-BTT, the users are involved in the interaction with the computer through STELT software, mainly exploiting the digital environment. Instead, the BTT-SCAN, represents a further enhanced version of the BTT integrating an Artificial Vision module, supported by a camera, able to scan and recognize the cubes' disposition through ArUco Markers. In this manner, the work of clinicians is supported by the automated diagnosis and the spatial cognition of individuals can be deepened considering the different strategies in cubes composition showed by participants. In spite of the advantages, the E-BTT and BTT-SCAN prototypes there have been encountered some failures in collecting the data; we will develop the new BTT enhanced version taking into the account the following suggestion. We will replace the cubes with new physical objects for three main reasons: Firstly, the cubes, in their shape, are not similar to bun and moreover we want to avoid *"blocks creations"*; secondly, the color of cubes has influenced the configurations of the participants who sometimes regrouped cubes of the same colour; thirdly, the thickness of the cubes creates shadows on the surface that compromise the data collection and the image processing of the artificial vision module.

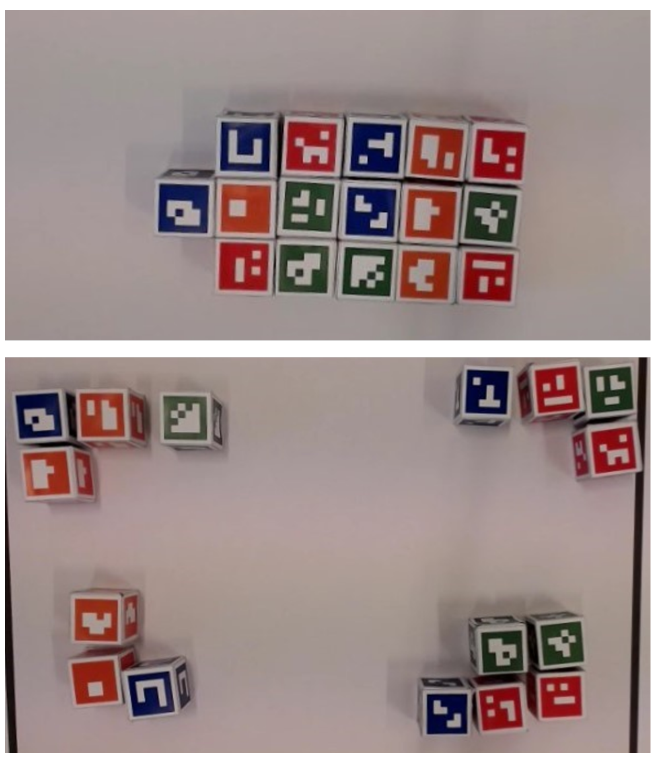

Fig. 2. Two different examples of *blocks creations*

For this reasons, new physical objects will be thin, round and black-and-white disks, detectable again through the ArUco Makers. In addition, we will utilize a surface (delimited by a wood frame) with a dimension of 60x45 cm in which individuals have to the dispose the 16 disks.

Fig. 3. New BTT-SCAN version

The STELT software will be substituted by ETAN, a platform that supports the detection of tangible user interfaces developed by Cerrato, Ponticorvo, Gigliotta, Bartolomeo and Miglino [7, 4] to investigate visuospatial behaviors of people in their proximal/peripersonal space, defined as the space immediately surrounding our bodies [24].

We will implement BTT with this platform to obtain a more informative data based on the spatial coordinates (x, y) of the objects and to track their position. Moreover, it will be possible to store the performances of the subjects both in a local and in an online database.

The data will be easily exported in a CSV le to access individuals performance for further analysis on the spatial skills of the healthy and clinical samples. ETAN has been developed for diagnostic purposes, but it would be also possible to implement a rehabilitative module able to adapt the task on the user needs (considering his level of abilities), starting a training and rehabilitation program for patients affected by USN and visuospatial impairments, following the principles of adaptive tutoring systems [19, 12]. Moreover, the implementation of the BTT with ETAN will be useful to improve stability and reliability compared to the other versions of the same test and to detect USN and different cognitive disorders related to visuospatial abilities. In order to benefit to the improvements mentioned above, it is necessary to administered the new prototype to healthy and clinical populations and to deep evaluate any weakness. Once collected data through ETAN, it will be possible develop also a learning analytics module able to track individuals performances through time and compare them with the rest

Fig. 4. ETAN: the software and the materials to perform BTT

of the population. In this manner we aim to design a new prototype able to better detect the presence of spatial cognition impairments of individuals and provide to the clinicians an useful tool able to support them during the diagnostic and rehabilitation procedure.

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