Hemineglect assessment and rehabilitation using a robotic serious game

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Abstract—Hemineglect is a condition where brain-damaged patients are impaired at perceiving and responding to the contralesional part of objects (allocentric hemineglect) and/or the contralesional part of space (egocentric hemineglect). The condition can also be accompanied by motor impairments. Although treatments exist, none are completely effective. The pipeline objective of our research is to develop a serious game that evaluates and rehabilitates the different forms of hemineglect according to the patient’s impairment severity. The first step towards this objective is the development and validation of a robotic assessment for egocentric hemineglect. We tested 12 stroke patients and 40 healthy control participants with the robotic hemineglect assessment. Patients were also assessed with two hemineglect standardized tests. Significant correlations between the robotic and standardized tests demonstrated a good validity for the assessment of egocentric hemineglect. Moreover, the robotic assessment showed a good sensitivity and specificity. Based on these results, we can identify the captures/components necessary for the serious game rehabilitation to adapt difficulty level in correspondance to the patient’s egocentric hemineglect impairment. Future steps in development will focus on the validation of the allocentric and motor hemineglect assessment.

Keywords—hemineglect; spatial attention; assessment; serious game; robot; brain-damage

I. BACKGROUND

Recent research shows that approximately one third of acute stroke patients present hemineglect (also named visuospatial neglect) [1]. The condition is heterogeneous, and leads to many different forms. Egocentric hemineglect refers to a failure to respond to contralesional stimuli from the patient’s viewpoint [2], whereas allocentric hemineglect is the failure to attend to the contralesional side of objects, irrespective of the object location from the patient’s viewpoint [2]. As well as visuospatial deficits, hemineglect can also lead to motor problems, either corresponding to an underutilisation of the contralesional limb in absence of muscle, strength, or sensation impairments, or corresponding to defective movements towards the contralesional hemifield [3], [4].

Fig. 1. Schematic representation of the overall project.
METHOD

Twelve stroke patients (63.8 ± 10.2 years and 13 ± 12.7 months post-onset) and forty mean age paired healthy controls (61.4 ± 12.7 years) were tested. The study was approved by the St-Luc hospital ethics committee and all participants gave their consent.

The REAplan rehabilitation robot (Axinesis®) was used for the development of the hemineglect assessment. The end-effector robot uses position and force sensors to allow for precise action measures in the horizontal plane. The robot has a visual interface for the patient, and a separate monitor for the therapist. For the present phase, the robotic hemineglect assessment consisted of a target pointing task that required the participant to find a musical conductor (target) randomly presented among musical instruments (distractors). The targets were complete or incomplete (where the object was missing left- or right-side allocentric features). For each display, a single target was randomly presented somewhere in the lateral space (egocentric, left-to-right). As soon as the complete target was perceived, the participant was instructed to make a push response of the end-effector towards a conductor’s baton image. However, if the target was incomplete, the participant made a pull response towards an image of a musical stand.

The healthy participants were only evaluated with the robotic hemineglect assessment. Patients were also assessed with two standardized cancellation tests; the Bells test [9] and the Apple test [10]. The order of the tests was counterbalanced between participants. The dependent variables were: percentage of contralateral space omissions, difference between percentage of omissions in contralateral compared to ipsilateral space (i.e., percentage of omission asymmetry), mean reaction time for correct answers in contralateral space, and difference between mean reaction time for correct answers in contralateral compared to ipsilateral space (i.e., mean reaction time asymmetry). Validity was analyzed with Spearman correlations. Norms for the robotic assessment were created using ninety-five percent confidence intervals, and Spearman correlations. Norms for the robotic hemineglect assessment had a sensitivity of 83% and a specificity of 67%.

RESULTS

Results showed correlation between percentage of omissions and mean reaction time in contralateral space (ρ = 0.811, p=0.002), and percentage of omission asymmetry and mean reaction time asymmetry (ρ = 0.674, p=0.023). Standardized test comparisons demonstrated correlation between percentage of contralateral space omissions on the robotic assessment and percentage of contralateral space omissions on the Bells (ρ = 0.696, p=0.012) and Apple tests (ρ = 0.851, p=0.000). Similarly, omission asymmetry percentage on the robotic assessment correlated with percentage of omissions asymmetry on the Apple test (ρ = 0.620, p=0.031), and showed some relation with the percentage of omission asymmetry on the Bells test (ρ = 0.511, p=0.089). Finally, comparison of our participants to norms showed that the robotic hemineglect assessment had a sensitivity of 83% and a specificity of 67%.

CONCLUSION & PERSPECTIVES

The present phase of our study demonstrated that the robotic assessment formed a valid tool to evaluate egocentric hemineglect, matching results from standardized tests. Moreover, the robotic test had a good sensitivity and specificity demonstrating value for diagnosis evaluation. These findings provide the captures necessary to reliably adapt the subsequent rehabilitation serious game in correspondence to the patient’s egocentric hemineglect severity. The game will predict when to trigger visual and motor cues that help the patient achieve a consistent success rate for re-learning. Future steps in development will focus on the validation of the allocentric and motor hemineglect assessment in order to calibrate the serious game in correspondence with the different hemineglect forms and severity.

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