A New 2D Interaction-based Method for the Behavioral Analysis of Instrumental Activities of Daily Living

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Keywords: Behavioral Analysis, 2D Interaction, Activity of Daily Living.

Abstract: In neuropsychology, many computerized solutions have been proposed in order to assess patients' functioning in activities of daily living, via realistic interactive simulation. In this context, most developed systems are based on simple devices, real time 2D interaction, and monoscopic 3D computer graphics environment. Behavioral analysis has drawn the interest of many domains, such as neuropsychology, ergonomics, web design, or virtual reality. However, advances on this topic remains fragmented in their respective areas. Thus, in computerized solutions applied to neuropsychology, the behavioral analysis does not take into account the data from interaction. The potential interest of computerized solutions is hence underexploited. In this paper, we propose a transdisciplinary solution, based on a finer analysis of 2D interaction data, such as stop duration. This method could reveal interesting aspects of users' behaviors.

1 INTRODUCTION

Intrumental Activities of Daily Living (IADL; e.g., cooking, shopping, driving) are assessed to help the diagnosis of dementia in clinical practice, as a recommended primary outcome in several kinds of research in dementia. Indeed, the IADL assessment permits to propose relevant solutions to help patients dealing with their everyday difficulties (Seligman et al., 2014).

In clinical practice, IADL assessment is generally done using questionnaires (e.g., IADL scale, Lawton and Brody, 1969). However, for an early detection or rehabilitation, they lack of objectivity and they are insufficient to provide a comprehensive view of the patients' everyday difficulties. Other traditional tests, which focus on different specific aspects of perception, cognition, or motricity, are insufficient to detect everyday difficulties for some patients (Lewis et al., 2011) and may fail to reflect the real measurements (Burgess et al., 2006; Chaytor and Schmitter-Edgecombe, 2003). In other words, the traditional tests lack of ecological validity (Campbell et al., 2009).

In response, occupational therapy and neuropsychology have developed various methods based on the performance in IADL activities, such as cooking in front of the experimenter. This real-world approach aims to provide a direct and comprehensive behavioral analysis of the patient on the IADL he/she has to perform. Nevertheless, such assessments are often difficult to set up, because of time consuming, perishable storage and cost, or potential risks (e.g., burn).

Several computer-based assessments have also been developed to submit patients to controlled situations with which they can act without risks. This approach typically uses traditional desktop human-computer interfaces (e.g., monitor, mouse). In the most basic configuration, the patient selects 2D graphics using 2D interaction techniques (e.g., mouse or touch-screen). However, these solutions lack of realism and do not allow a fine behavior analysis. Consequently, several studies using such solutions have reported a little predictive value of everyday functioning (Armstrong et al., 2013; Schultheis et al., 2002). For these reasons, Virtual Reality (VR) techniques have been proposed to assess IADL (Louisy et al., 2003). VR provides 3D pseudo-natural real-time multimodal virtual environments (Arnaldi et al., 2003), and 3D interaction techniques based on real-world interaction (e.g., pointing, walking-in-place). In this context, the use of wireless motion capture devices (e.g., Microsoft Kinect^{TM}) allows pseudo-natural users'

Verhulst E., Foloppe D., Richard P., Banville F. and Allain P.
A New 2D Interaction-based Method for the Behavioral Analysis of Instrumental Activities of Daily Living.
DOI: 10.5220/0006255901460151
In *Proceedings of the 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2017)*, pages 146-151
ISBN: 978-989-758-229-5

interaction. However, several limitations compromise the use of VR techniques, especially for for elderly or vulnerable patients. For example, 3D gestures-based selection or manipulation techniques require relatively high energy expenditure for them and therefore cannot be used in long experiments (Sousa Santos et al., 2009; Verhulst et al., 2016). In addition, some VR systems lack of portability, and are not easy to setup at home. Moreover, a recent study about VR has pointed out the lack of ecological validity of the fully immersive systems (Neguţ et al., 2016). The authors have suggested that VR adds complexity and difficulty, and cognitive load, compared to the real world.

A good compromise between these 2 approaches has been used, as a kind of technically non-immersive system. Such systems are VR-based, because they simulate 3D IADL environments, propose a real-time interaction, and use VR as science to develop realimic experience of tasks. However, like in the most basic solution, they use a 2D desktop configuration. When the manipulation of several objects is a key element of the evaluated tasks (e.g., cooking, laundry, small home repairs), mice or touch screens are typically used. In other words, these systems use a 2D interaction interface, to interact with 3D computer graphics environments, displayed monoscopically (Richard et al., 2010; Allain et al., 2014; Zhang et al., 2003). Traditional desktop interfaces offer a good portability for clinical practice. The monoscopic display avoids discrepancy and eye fatigue (Teather and Stuerzlinger, 2015) for assessed patients. Moreover, several studies have compared the use of the mouse in 2D and 3D environments, showing that the use of mouse is easier and more accurate for 2D interaction than for 3D interaction (Teather and Stuerzlinger, 2015; Ware and Lowther, 1997). Mice and touch screens are commonly used 2D interaction interfaces. However, even if mice and touch screens have a comparable efficiency, users make more errors when using a touch screen (Forlines et al., 2007), especially for the elderly, due to bad wrist posture (Motti and Caine, 2016). Importantly, research on IADL assessment using such RV-based systems has shown adequate reliable and valid results, although these systems were technically non-immersive. Moreover, they can provide explicative data about the origins of this limitation (Banville and Nolin, 2012).

A remaining problem with 3D computer graphics environment based on 2D interaction techniques is the difficulty to control the mouse pointer mouvements, especially for the elderly or some disabled people. This problem may lead to artificial unwanted errors. Consequently, the ecological validity of obtained measured could be affected. Taking into account the wide use of this kind of systems, there is a crucial need to develop solutions to distinguish usability errors from cognitive errors. To achieve a better comprehension of users abilities in computer-based assessment, we propose a new method to investigate behavior of patients with IADL limitations due to cognitive deficits by analyzing mouse activities such as pathways and mouse events (e.g. click).

The following Section provides a short survey of the related works concerning real-world assessments of IADL (types of errors), and in mouse data analysis (mouse interaction with 2D content). Then, we propose an alternative method to analyze users performance, taking into account usability errors and cognitive errors. The paper ends by a conclusion and tracks for future works.

2 RELATED WORKS

2.1 Types of Errors

Using the approach based on performance in the real-world, neuropsychological research on IADL difculties has yielded observable taxonomies of errors. In this context, (Giovannetti et al., 2008) have proposed and formulated the commission-omission model. This model postulate that global cognitive deficit and episodic memory deficit lead patients to forget the steps associated with management of the task (i.e., produce omissions errors). Thus, a deficit in executive functions leads patients to incorrectly perform pertinent actions or to perform no relevant actions (i.e., produce commissions omissions). The commissions errors do not prevent the tasks completion, but can make more difficult the goals achievement. There are several types of commission errors such as perseveration where participants realize the same action sequence more than one time, the omission-anticipation where they make an action step in a non-conventional order and finally substitution where they select a given object semantically related to the expected object. For instance, turning on the coffee machine before filling it with water is a commission error, while to not put water at all is an omission error.

In line with the commission-omission model, Seligman et al. (2014) have proposed to take account of the inefficient actions, but not overtly erroneous, called micro-errors. The micro-errors include too many steps in the realization of the task, wrong sequencing and microslips which are initialization of an unfinished action. Micro-errors are pertinent for detecting cognitive decline in pathological ageing (Seligman et al., 2014).

2.2 2D Interaction with 2D Content

The use of mouse is known by a majority of people and does not cause fatigue for the user (Besançon et al., 2016). Several studies have investigated the interest of the mouse movements analysis. Although mainly conducted in a context of free web information searching (Shapira et al., 2006; Claypool et al., 2001; Guo and Agichtein, 2008), they provide useful results. For instance, when participants focus on website reading, they produce more mouse movements (Shapira et al., 2006), and more mouse wheels (Claypool et al., 2001). Guo and Agichtein (2008) have found that, when users want to switch to another internet link, they make direct movements into the target. When they are reading or searching for information, they spent more time on the website, and make longer and random movements with the mouse (Guo and Agichtein, 2008). Overall, users make long mouse movements when they are cognitively involved, whereas they make quick movements, doing a motor task (e.g., clicking on a link), when they are focusing on some information (Guo and Agichtein, 2008).

Other mouse movements analyses have shown the usefulness of this approach, to extract behavioral patterns, and to discriminate profile groups. For example, Seelye et al. (2015) have pointed out that a group of people with mild cognitive impairment was less efficient to use the mouse than a group of healthy elderly. The impaired people needed more time to click on icons during web searching, make large mouse movements, and make fewer movements, compared to the healthy elderly. More generally, the elderly could have issues with the mouse, especially for the most complex actions, like double click. Smith et al. (1999) have shown that the elderly spent more time to move the mouse, and make longer path to reach a target, because they are less precise compared to younger people.

3 PROPOSAL

We propose to add the analysis of data from interaction, in the context of the IADL assessment by "non-immersive VR" systems. The steps of the task which are compromised can be detected according to the omission-commission model (Giovannetti et al., 2008, 2012). The analysis of data from interaction could distinguish usability errors from cognitive errors. We hence could improve the validity of assessment by "non-immersive VR" systems. Moreover, we could specify new behavioral patterns, similarly to web searching study and in the Second Life (Harris et al., 2009). We hence could provide new data about how/why some steps are compromised.

3.1 Proposed Data Analysis

Data from interaction can be collected while the participant performs the computerized task. These data include mouse path, halt time, click(s) on item, wrong click, drag and drop, and movement velocity. Different kinds of data could be displayed and replayed, in the experimented environment, for individual or group synthesis (see Fig. 1).

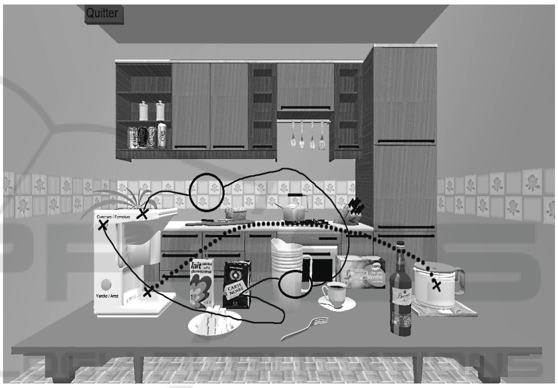

Figure 1: Example of visualization of some mouse data for a coffee-making task: Mouse path (full line), halt time (circle), click (cross), drag and drop (dotted line).

The mouse path includes an origin, an end, and several sub-movements. Sub-mouvements can be defined by their length and direction (Hourcade, 2006) separated by pauses (Almanji et al., 2014). Generally, the first sub-movement has a higher velocity and others are slower (Thompson et al., 2007). We expect that, during the phases of cognitive planing, the mouse movements will be slow and random, whereas they will be faster during a planned action.

Several clicks on an object could reveal a lack of control-display ratio between click and objects animation, or a micro-error (Seligman et al., 2014).

A wrong click is a click outside a point of interest. This kind of data could reveal bad system usability or cognitive perturbations.

3.2 Planned Experiment

The data analysis that we propose can be used in various contexts. In our case, we project to use it in

Figure 2: Experimental setup (left) and screenshot of the coffee task (right) from our previous work.

line with our previous work on IADL assessment in impaired people (Allain et al., 2014; Richard et al., 2010). More clearly (see Fig.2), we will use a system based on VR, but non-immersive, which proposes to perform a coffee-making task, in a virtual kitchen (Richard et al., 2010). Coffee-making tasks are commonly used in the ecological assessment and rehabilitation of IADL (Allain et al., 2014; Foloppe et al., 2015; Zhang et al., 2003). In our task, patient has to pick and place virtual objects, in order to prepare a cup of coffee with milk and sugar. The mouse allows controlling the position of the virtual objects on the vertical and horizontal axis. The virtual objects are automatically moved in depth. A behavioral analysis according the omission-commission is available (Allain et al., 2014). We plan to integrate the analysis of mouse data, and complete the behavioral analysis.

We wonder whether the patterns obtained from this kind of data are similar to those obtained from our current assessment (Allain et al., 2014). We will conduct an experiment in young people, old people, and cognitively impaired people. We expect to find different behavioral patterns in accordance with the age of the population. Indeed, the elderly could make more pauses and more unwanted clicks, especially if they have mild cognitive impairment, than young adults. Behavioral pattern could help to make a distinction between profile groups. Indeed, monitoring data will permit to detect pattern in the use of a virtual kitchen to prepare a cup of coffee. The data recorded by the mouse could help us to detect moment where participant are thinking (reflections steps), where untimely clicks are made and actions sequence realization could help to detect where mistakes occurs and what kind of errors it is according the commission-omission model (Giovannetti et al., 2008, 2012). Furthermore; we could make in relation monitoring data and actions sequence realization to detect in which case participant needs more time to prepare the cup of coffee. Is it after an error or in the same moment for several participants?

4 CONCLUSION AND FUTURE WORK

3D computer graphics environments enable to assess patients behaviors in ecological contexts. The aim of this proposal is to suggest a complementary method to analyze participants performance during cognitive tasks. Actually, error analyzes help to understand participants performance, but it is difficult to discriminate usability errors from errors due to cognitive perturbations. For instance, some variables (e.g., time completion) can inform on participants performance and on their ability to interact with the virtual environments. In order to differentiate cognitive errors from usability errors we propose to analyze mouse movements. In this context, we will try to identify behavioral patterns during the simulated task and compare them with those found in a web searching activity (Seelye et al., 2015; Shapira et al., 2006; Claypool et al., 2001). Our analyzes could allow discriminating usability errors from cognitive perturbations errors. In addition, the mouse movements analysis could help us to have a better understanding of the participants performance and could be adapted in several virtual environments with 2D interaction. Moreover as mice do not cause fatigue to the users (Besançon et al., 2016), we could think about workload associated to interaction technique in VR. Indeed, a recent study has pointed out that the lack of ecological validity of the fully immersive systems (Neguţ et al., 2016). The authors have suggested that VR adds complexity and difficulty, and cognitive load, compared to the real world. This suggestion is comforted by Allain et al. (2014), who found more errors in a virtual coffee task than during the same task in reality.

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