REVUE NEUROLOGIQUE XXX (2016) XXX–XXX

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

General review

Ecological assessment of divided attention: What about the current tools and the relevancy of virtual reality

C. Lopez Maïté *, *D. Gaétane*, *C. Axel*

Université Libre de Bruxelles (UNI – ULB), Neurosciences Institute, Center for Research in Cognition and Neurosciences (CRCN), Consciousness, Cognition & Computation (CO3), avenue F.D. Roosevelt 50, 1050 Brussels, Belgium

INFO ARTICLE

Article history:
Received 7 June 2015
Received in revised form
23 December 2015
Accepted 8 January 2016
Available online xxx

Keywords:
Neuropsychology tests
Attention
Virtual reality

ABSTRACT

The ability to perform two tasks simultaneously has become increasingly important as attention-demanding technologies have become more common in daily life. This type of attentional resources allocation is commonly called ''divided attention''. Because of the importance of divided attention in natural world settings, substantial efforts have been made recently so as to promote an integrated, realistic assessment of functional abilities in dual-task paradigms. In this context, virtual reality methods appear to be a good solution. However to date, there has been little discussion on validity of such methods. Here, we offer a comparative review of conventional tools used to assess divided attention and of the first virtual reality studies (mostly from the field of road and pedestrian safety). The ecological character of virtual environments leads to a better understanding of the influence of dual-task settings and also makes it possible to clarify issues such as the utility of hands-free phones. After discussing the theoretical and clinical contributions of these studies, we discuss the limits of virtual reality assessment, focusing in particular: (i) on the challenges associated with lack of familiarity with new technological devices; (ii) on the validity of the ecological character of virtual environments; and (iii) on the question of whether the results obtained in a specific context can be generalized to all dual-task situations typical of daily life. To overcome the limitations associated with virtual reality, we propose: (i) to include a standardized familiarization phase in assessment protocols so as to limit the interference caused by the use of new technologies; (ii) to systematically compare virtual reality performance with conventional tests or real-life tests; and (iii) to design dual-task scenarios that are independent from the patient's expertise on one of the two tasks. We conclude that virtual reality appears to constitute a useful tool when used in combination with more conventional tests.

* *Corresponding author.*
E-mail address: maite.camara.lopez@ulb.ac.be (C. Lopez Maïté).
http://dx.doi.org/10.1016/j.neurol.2016.01.399

Please cite this article in press as: Lopez Maïté C, et al. Ecological assessment of divided attention: What about the current tools and the relevancy of virtual reality. Revue neurologique (2016), http://dx.doi.org/10.1016/j.neurol.2016.01.399

1. Divided attention: theories and current assessment tools

1.1. Definitions and background

Our cognitive system, considered as an information processing system, is composed of a group of sub-components executing diverse processes, including attentional processes. The basic process of cognition seen a prerequisite of all cognitive functions [1]. This attentional system, viewed first as a unique construct allowing an agent to focalize on environmental stimuli, progressively evolved into a multiple concept of attention. Van Zomeren and Brouwer thus proposed a classification of attentional functions divided into two distinct categories: one relative to attentional intensity and the other involving attentional selectivity [2].

Attentional intensity designates the level of attention required to maintain efficient response to short-duration (alert) or long-duration (vigilance and sustained attention) stimuli. Vigilance maintains a level of attention sufficient to execute long monotonous tasks despite a small number of stimuli [3] – for instance a security agent watching video monitors. Sustained attention is solicited in situations characterized by a continuous stream of stimuli that impose uninterrupted active processing – for example proactive attention during a debate. Attentional selectivity – composed of selective attention, divided attention and flexibility – enables the subject to focus on pertinent objective-related elements. Selective attention, characterized by the capacity to focus attention on specific stimuli, involves a dual mechanism whereby attention is centered on a given object and irrelevant elements are inhibited. A continuously alternating focus of attention is called flexibility. Finally, divided attention is defined as the capacity to execute several tasks simultaneously [3].

This review of the literature basically concerns divided attention – also termed shared attention. Driving a motor vehicle is often used as a typical example of this type of attention in the presence of multiple stimuli. This complex cognitive skill involves two distinct mechanisms: first, simultaneous processing of several sources of information input – e.g. understanding what several people are saying; and secondly, simultaneous execution of multiple tasks – e.g. telephoning while driving. More specifically, the first mechanism involves divided attention while the second is called the dual-task paradigm [4].

Allocation of attentional resources is an adaptive process known to have deleterious effects in the dual-task setting. Consequently, when the two tasks to be performed together both involve a high level of cognition and attention, task execution is necessarily affected [5]. The phenomenon is well documented in the literature, yet the underlying mechanisms of the deleterious dual-task effect still incite a growing body of research. An individual's ability to allocate attentional resources among the different sub-tasks to be performed depends on three main factors: inter-task interference; task difficulty; and individual expertise for each task [6]. Task similarity (stimuli presentation, response modality) is the first factor affecting task execution. The implication of a common modality increases the degree of reciprocal interference between the two tasks, triggering less efficient performance. The second factor involves task complexity. Tests combining two tasks offer an objective approach to understand this factor. A test that may seem easy to perform in the single-task condition becomes more complex when combined with a second task. Finally, the degree of expertise, and eventually automatic task execution, is the third factor influencing an individual's ability to allocate attentional resources to different tasks [6]. Indeed, since the conscious attentional resources needed to execute a routine or automatic task are minimal, the task can be performed rapidly without interfering with associated tasks. Expertise frees resources for controlled conscious execution of a second task [1].

Classically, dual-task paradigm is used to apprehend the concept of attentional resources allocation. For such tasks, the participant is instructed to react rapidly to two different items (S1 and S2) displayed among different stimuli. For instance, the participant has to identify a given figure (S1) and a specific sound (S2) by pressing the response button as fast as possible. Performance is measured with two variables: reaction time and number of correct responses. In the dual-task paradigm, there is always a certain delay between the first and second stimuli. The first one (S1) has to be processed before the second (S2), a phenomenon explained by the Psychological Refractory Period (PRP). Because of the PRP following the first stimuli (S1), the participant would be unable to process the second stimuli to produce the appropriate response for S1 [5]. For Pashler [7], the PRP can be considered to be an attentional bottleneck that constrain the amount of information that can be processed at any given moment in time. The selection of the response to S1 would inhibit – because of the attentional bottleneck – an appropriate response to S2, and consequently lengthen the response time. This theory on the effect of interstimuli temporal proximity predicts that response time will lengthen for S2 as the time interval between the displays of the two stimuli shortens. Tombu and Jolicoeur [8] questioned the theory of Pashler [7] by demonstrating a modulation of the PRP effect according to the importance attributed to a specific task. Thus, if the participant is specifically instructed to allocate attentional capacities mainly on S2, the response time on the first task become increasingly long.

Cognitive processes potentially implicated in dual-task performance remain a subject of ongoing debate. Executing dual-tasks implies the involvement of several cognitive functions including processing speed, working memory, and more general executive functions [2,9]. The attentional control of dual-task execution as well as the management of these same attentional resources – allocation versus withdrawal of attentional resources – would explain the overlapping terminology between attentional and executive functions. Thus, while certain authors describe divided attention as a purely attentional function, others focus more on the executive aspect [10]. In order to avoid any misunderstanding in terminology, Cicerone and Maestas [11] suggested using the two terms in combination: attentional-executive functions.

In conclusion, factors potentially affecting the execution of two tasks simultaneously include the display or response modalities, task difficulty, and level of expertise.

Please cite this article in press as: Lopez Maïté C, et al. Ecological assessment of divided attention: What about the current tools and the relevancy of virtual reality. Revue neurologique (2016), http://dx.doi.org/10.1016/j.neurol.2016.01.399