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The measurement of visual sampling during real-world activity in Parkinson's disease and healthy controls: A structured literature review

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HIGHLIGHTS

- Techniques for objective measurement of visual sampling lack consistency.
- Reliability and validity of instruments has not been yet established.
- Testing recommendations include assessment of basic visual function and cognition.
- This review informs the development of robust protocols.

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ABSTRACT

Background: Visual sampling techniques are used to investigate the complex role of vision during real-world activities in Parkinson's disease. Earlier research is limited to static simple tasks or measurement of eye movements alone, but more recent investigations involve more real-world activities. The approach to the objective measurement of eye movements varies with respect to instrumentation, testing protocols, and mediating factors that may influence visual sampling.
Objectives: The aim of this review was to examine previous work measuring visual sampling during real-world activities in Parkinson's disease to inform the development of robust protocols. Within this review a real-world activity was considered to be a goal-orientated motor task involving more than one body segment such as reaching or walking.
Methods: Medline, Embase, PsychInfo, Scopus, Web of Knowledge, PubMed and the Cochrane library databases were searched. Two independent reviewers and an adjudicator screened articles that described quantitative visual sampling in people with Parkinson's disease and healthy controls.
Results: Twenty full-text articles were screened and 15 met inclusion/exclusion criteria. A wide range of instruments and outcome measures were reported which were generally used in a task-dependent manner. Instrument reliability and validity was insufficiently reported in all studies. Few studies considered mediators of visual sampling such as visual or cognitive deficits.
Conclusions: Future research is required to accurately characterise visual impairments in Parkinson's disease and during real-world activities. Composite use of instruments may be required to achieve reliability and validity of visual sampling outcomes which need to be standardised. Recommendations also include assessment of cognition and basic visual function.

Contents

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1. Introduction

Visual sampling (VS) is the combination of fixations and saccades that are required to gather information about our environment when performing a real-world activity. VS has been assessed using a variety of methods since the 1700s, evolving from simple photographic technology to more recently the use of mobile infra-red eye-tracking (Land, 2006; Porterfield, 1752). Eye-tracking involves two distinguishable movements of the eye; activity that stabilises the fovea (fixations) on areas of interest (AOI), and activity that rapidly shifts the fovea to bring AOI into high visual acuity (saccades) (Anderson and MacAskill, 2013). A combination of fixations and saccades provide the mechanisms through which we sample our visual environment (McPeek et al., 2000; Deubel, 2003; Tatler, 2009). Advancements in eye-tracking technology have enabled VS to be monitored during real-world activity (e.g. walking, obstacle crossing, driving). This progress is vital as VS is a critical feature of motor control, which is task-dependent and relates to specific goals (Marigold and Patla, 2007). For example: during locomotion over even ground in healthy control subjects long fixation durations are not necessarily required, yet saccadic frequency, amplitude and duration of fixations increase in healthy subjects when walking over uneven terrain (Land, 2006; Patla and Greig, 2006). The co-ordination of the eyes, head, trunk and other body segments during real-world activity requires visuomotor control to guide and organise linked-segment interactions. Motor control and visual mechanisms are also inter-linked with attentional networks, which are governed by cognitive ('top-down') processes (Botha and Carr, 2012). Therefore, disease-specific impairments of motor control (Joti et al., 2007; Konczak et al., 2009) and cognition (Archibald et al., 2013) potentially mediate visual function.

Parkinson's disease (PD) is a progressive neurodegenerative disease associated with impaired motor control (Konczak et al., 2009) and a range of cognitive and visual deficits. Motor symptoms such as bradykinesia (slow movement) and akinesia (impaired movement) are evident in limb and eye movements in PD during real-world activity. For example, bradykinesia can affect reaching (Schettino et al., 2006), pointing (Adamovich et al., 2001; Bekkering et al., 2001; Boisseau et al., 2002; Klockgether and Dichgans, 1994) and force control (Vaillancourt et al., 2001b, 2001a). In addition, impaired visuo-perceptual and basic visual functions such as reduced contrast sensitivity are reported by up to 81% (Verbaan et al., 2007) and 78% (Davidsdottir et al., 2005) of PD subjects respectively. These symptoms are seen at an early stage in PD and are associated with functional decline, freezing of gait (FOG) and falls. Investigation into VS during real-world activity in PD is warranted, to further clarify the links between these motor, cognitive and visual impairments. Eye-tracking technology has been used to further understand the visual strategies of PD subjects since the 1960's (Terao et al., 2011; van Stockum et al., 2012), demonstrating VS impairments, such as hypometric voluntary (van Stockum et al., 2012; Anderson and MacAskill, 2013) and variable reflexive (Chambers and Prescott, 2010) saccades. However until recently most research using eye-trackers involved small sample sizes (Anderson and MacAskill, 2013). Similarly most PD studies of VS are limited to static examination of eye movements alone or involve simple single-segment motor tasks (e.g. mouse clicks). Of the PD studies investigating VS during real-world activity, a wide range of protocols has been used indicating a lack of standardisation, which limits VS interpretation. Investigators who want to conduct similar research are left with the choice between numerous protocols, which differ in many respects. In the process of developing robust protocols it is often helpful to have evidence-based recommendations. We therefore examined previous work that assessed VS during real-world activities in PD and healthy control (HC) participants, in order to provide some guidance regarding the selection of appropriate methodology.

We focused the review on the following: (1) VS instrumentation used during real-world activities involving both PD and HC; (2) commonly reported VS outcomes; (3) PD specific influences on these visual outcomes; and, (4) recommendations concerning protocol. For the purpose of this review a real-world activity was considered to be a goal-orientated motor task, which involved more than one body segment (such as walking, reaching, turning etc.).

2. Methods

2.1. Search strategy

The key terms were "Parkinson's disease", "visual sampling" and a "motor task". A list of synonyms was created for each key term (Fig. 1). Key terms were matched and exploded with medical subject headings (MeSH) in each separate database where appropriate. Databases searched included Medline (from 1950), Embase (from 1974), PsychInfo (from 1806), Scopus, Web of Knowledge (from 1900), PubMed (from 1950) and the Cochrane library (from 1800) to February 2013. Studies were relevant if they incorporated terminology which focused on VS during a real-world activity in both PD and healthy control subjects in the title, abstract or keywords. Articles with titles related to 'sleep', 'monkeys', 'rats' and 'hallucinations' were excluded using separate key terms.

An initial title screen for relevant articles was performed by the reviewer (SS) once the searched database results had been combined. After the initial title screen, both the titles and abstracts of the selected articles were reviewed by two independent reviewers