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1 Title:THE POTENTIAL AND VALUE OF OBJECTIVE EYE TRACKING IN THE
2 OPHTHALMOLOGY CLINIC

3

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37 Conflicts of Interest

38 The authors have no conflicts of interest.

39

40 Running title: Objective Eye Tracking in the clinic

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45 **Main Text**

46 Numerous research studies have demonstrated the scope and value of eye
47 movement recording (EMR). There is now potential for EMR to be helpful in a
48 range of clinical contexts and it could be developed as a routine part of the
49 repertoire of clinical investigations offered by the NHS, at least in tertiary centres.
50 We highlight potential uses and challenges below, as a prelude to further
51 development and debate.

52 *Diagnosis*

53 EMR in patients with nystagmus is already increasingly used clinically and provides
54 the only method for identifying the exact waveform[1, 2]. A classic example is
55 identifying the characteristic accelerating waveform of infantile nystagmus
56 syndrome (INS), which obviates the need for urgent investigations of newly-
57 diagnosed nystagmus, saving the patients and the NHS time and money. EMR
58 may also indicate the cause of an abnormal head posture (AHP) and identify the
59 best option for treatment. For example, an AHP may be adopted to use a null point
60 in subclinical, previously undiagnosed INS, or to put an eye into adduction if the
61 patient has latent nystagmus.

62 However, EMR can help in the management of patients other than those with
63 nystagmus. Examples include:

64 In Parkinson's disease, EMRs of saccades help differentiate between dementia
65 with Lewy bodies, progressive supranuclear palsy, corticobasal degeneration, and
66 multiple system atrophy[3].

67 EMR will differentiate between Gaucher Disease Type 1 and Type 3[4]. This is
68 particularly important, as there are different treatment pathways for these patient
69 groups. Abnormal EMR metrics have also been reported in children with three rare
70 metabolic diseases: Tyrosinemia III, Niemann Pick C and Morquio syndrome[5, 6] –
71 potentially allowing treatment to be started earlier in the disease process[6].

72 In psychiatry, EMR performance on the antisaccade task is affected (see:[7]) and
73 EMR metrics have been used to classify cases of schizophrenia vs controls with
74 87-98% accuracy [8] which again may allow earlier and more accurate diagnosis,
75 with earlier treatment and support.

76 *Screening of at-risk individuals*

77 There is a growing body of evidence that EMR may be useful in the screening of
78 individuals at risk of disorders including Huntington's[9], Alzheimer's[10, 11] and
79 Parkinson's[12] Diseases.

80 *Monitoring of disease progression and of response to treatment*

81 The EMR abnormalities in Niemann Pick C, including curved saccades, increase in
82 magnitude with disease severity suggesting that these measures would also be
83 useful in monitoring disease progression. Also, in Parkinson's Disease, the extent
84 of EMR abnormalities is related to disease progression[13] and responsiveness to
85 treatment[14].

86 Although these results are encouraging, it is likely that EMR alone will only rarely, if
87 ever, be used as the only diagnostic criterion. However diagnostic pathways which
88 include EMR alongside, for example MR imaging[15], are likely to be shorter and
89 more accurate. Whilst the individual conditions may be rare, such as the metabolic
90 disorders, there are a much larger number of patients who present with early or
91 non-specific difficulties in whom treatable metabolic or neurological disease needs
92 to be ruled out, and therefore, specialist services that care for many patient groups
93 may benefit from access to reliable EMR within the NHS.

94 The objective and quantitative measurement of eye movements has a long history
95 dating back to the early 20th Century[16]. Early methods were uncomfortable and
96 invasive, and analysis of the resulting data was time-consuming. However, the
97 advent of both powerful personal computing and fast video-based recording
98 systems has led to a step-change in the last 15 years in this technology. EMR has
99 become standard in a wide range of settings including Consumer Research,
100 Human-Computer Interaction and Virtual Reality. Alongside this, work on both the
101 neurophysiology of eye movement control[17] and the detailed study of human eye
102 movement behaviour[18] means that we can map this visual-motor behaviour onto
103 the patterns of activity across a well studied and extensive brain network.

104 Routine recording of eye movements in a specialist clinical setting is now therefore
105 technically feasible and would provide a sensitive, quantitative and objective
106 method to aid diagnosis and management for a range of patients. However, despite
107 this potential benefit as a clinical tool, there are considerable challenges associated
108 with both introducing eye tracking into clinical practice and making it cost-effective.
109 We are still some way from having eye tracking hardware that is able to
110 successfully record the eye movements of every patient, whatever their age and

111 level of ability. We need a common suite of behavioural assays that are agreed
112 upon by the wider community, with normative data[19].

113 We would need to identify which groups of staff would carry out the assessments,
114 what training they would need, and how and by whom the resulting data should be
115 reported. One model is to develop inbuilt test paradigms and proforma reports that
116 include normative data, to limit the expertise required by the individual setting up
117 the test and make EMR accessible to a range of users. However, this highlights the
118 important issue of expertise in interpreting clinical eye movements. EMR may be
119 used to look for very specific abnormalities in an individual patient and a targeted
120 approach (as opposed to a general battery of tests) may be important for efficiency
121 and to address the key clinical question for that patient, especially for children. The
122 choice between a targeted or comprehensive approach requires both technical
123 ability and specific expertise. Training is required, but experience is also important
124 (as any clinician knows). Currently, there is no training offered and no recognised
125 training pathway. One possible route is to set up training for eye movement clinical
126 scientists, which could eventually become registrable with the Health and Care
127 Professions Council (HCPC). As an example, one of us (CH) is registered with the
128 HCPC as a 'Clinical Scientist' (which is a protected title) with designated expertise
129 in eye movements (the only one we are aware of). This avenue could be explored
130 as a way forward to formalise (and regulate) clinical oculomotor expertise.

131 EMR is already widely used in advertising, the aviation industry, rehabilitation
132 services, computer gaming and virtual reality equipment. The time has come to
133 explore how best to deploy this technology to the benefit of patients and the NHS.

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