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

2 OPHTHALMOLOGY CLINIC

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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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196   **Footnotes:**

197   None

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