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Review article

A survey on stimuli for visual cortical function assessment in infants

Farveh Daneshvarfard [a,b], Nasrin Maarefi [c], Hamid Abrishami Moghaddam [a,b,*], Fabrice Wallois [b,d]

[a] Faculty of Electrical Engineering, K.N. Toosi University of Technology, Tehran, Iran
[b] Inserm UMR 1105, Faculté de Médecine, Université de Picardie Jules Verne, Amiens, France
[c] Faculty of Computer Engineering, K.N. Toosi University of Technology, Tehran, Iran
[d] Inserm UMR 1105, Centre Hospitalier Universitaire d'Amiens, Amiens, France

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Abstract

Visual processing, as a significant and complex functionality of the human brain, changes during the life span with the most developmental changes in the infancy. Different types of visual stimuli are needed for evaluating different functionalities of the infants' visual system. Selecting appropriate visual stimuli is an important issue in evaluating visual cortical functions in infants. Properties of stimulation influence responses of visual system and must be adjusted according to the age and specific function which is going to be investigated. In this review, the most commonly used stimuli to elicit visual evoked potentials (VEPs) are evaluated and characteristics of VEPs extracted by these stimulations are studied. Furthermore, various studies investigating different functionalities such as selectivity for orientation and directional motion are presented. Valuable results regarding emerging and maturation times of different functions and normative data for clinical diagnosis are provided by these studies.

Keywords: Visual stimuli; Visual functionality; Infants; Visual evoked potentials

1. Introduction

Visual processing, as a significant functionality of the human brain, is not a fixed ability at birth and develops during the infancy. Different types of visual stimuli are needed for evaluating these developmental changes in infants' visual system. Appropriate stimuli are selected based on the infant's age and his/her perception of the environment. Newborns are poor in fixation and discrimination of color and orientation. Therefore, they are mostly investigated by black and white stimuli, especially different types of checkerboards and designs with angles. By 3 months, they are attracted to colored objects and are capable of glancing at smaller objects as small as 2.5 cm. Furthermore, visual attention and visual searching begin in this period of time. The infant can fixate at 1 m at 5–6 months and his/her acuity improves rapidly to near maturity by 6–9 months of age. Between 9 months and 1 year, the infant is alert to unfamiliar people and objects. Visual acuity is

* Corresponding author at: Department of Biomedical Engineering, Faculty of Electrical Engineering, K.N. Toosi University of Technology, Seyedkhandan, Dr. Shariati Ave, P.O. Box 16315-1355, Tehran, Iran.
E-mail addresses: f.daneshvarfard@ee.kntu.ac.ir (F. Daneshvarfard), n.maarefi@email.kntu.ac.ir (N. Maarefi), hamid.abrishami@u-picardie.fr (H. Abrishami Moghaddam), fabrice.wallois@u-picardie.fr (F. Wallois).

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between 20/20[1] and 20/30 at 2 years and the child's brain functions are near to adult basic sensory processing abilities at 2–5 years of age [1].

Development of visual acuity and functionality is evaluated using a preferential looking (PL) test or the visual evoked potential (VEP) recordings. In a PL experiment, the subject is presented with two stimulus fields, including the target and non-target regions (e.g. black and white stripes as the target and homogeneous gray area as the background). The location of the target is randomly alternated. Typically, infants will look at the target rather than the background, in the case of target detection. Beside this behavioral method of vision evaluation, visual evoked potentials are also used to assess the integrity and maturity of the visual system in infants. VEPs refer to electrical potentials, initiated by brief visual stimuli. VEP waveforms are extracted from the electro-encephalogram (EEG) by signal averaging. They are used for measuring functional integrity of the visual pathways from retina via the optic nerves to the visual cortex of the brain [2].

This paper covers an evaluation of different types of visual stimuli and the most commonly used stimulations to initiate visual evoked potentials. It also tends to provide some information about designing proper visual stimuli for investigating different functionalities of the infants' brain. Contrast and orientation sensitivity and direction of motion recognition, as well as color vision, are examples of different functionalities which can be studied separately through specific kinds of stimuli.

2. Patterned and flashed stimuli

Flash, pattern reversal (PR) and pattern onset/offset are three common types of stimuli used in evaluating visual functionality. A photo-stimulator, as a flash stimulus, requires minimal cooperation of the patient and is well suited for the case of poor optical quality or poor vision. The PR stimulus consists of black and white checks or gratings which reverse their light and dark regions, alternatively. Overall luminance of the pattern must be constant during the reversal. The most significant parameters for defining this stimulus include visual angle of each check or the spatial frequency of bars or gratings. PR is the most preferred stimuli in clinical purposes because of its low variability in waveform and timing. For pattern onset/offset, the pattern is abruptly exchanged with a gray background of the same overall luminance. This stimulus is best suited for detection of malingering and for use in patients with nystagmus [3].

VEPs may be elicited by either patterned or flashed visual stimuli. Stimulation at low rates (up to 4/s) will lead to "transient" VEPs and that of higher rates (10/s or higher) will produce responses that relatively oscillate at the frequency of stimulation and are called "steady-state" VEPs. One of the advantages of steady-state evoked potentials over transient evoked potentials is that they are not much affected by psychological variables such as attention and consequently, they are less variable [4]. Characteristics of steady-state evoked potentials and their advantages as well as details of analysis in frequency domain have been summarized by Regan [4]. Responses elicited by patterned stimuli are "pattern" VEPs or PVEPs and those elicited by flashed stimuli are "flash" VEPs or FVEPs. PVEPs are less variant to intra- and inter individual variability and detect minor visual pathway abnormality more accurately than FVEPs. Checkerboard PR and sinusoidal grating are the most widely used pattern stimuli because of their relative simplicity and reliability. Furthermore, flashed stimuli are more convenient for patients who are unable to fixate or attend to the stimulus [5].

VEP characteristics are affected by check size and visual field span of the patterned stimuli. Changing these parameters allows selective testing of specific regions of the visual pathway. In most clinical experiments, patients are screened using a video display with field subtending 10–40 arc deg and check size of about 1 arc deg. For most of clinical applications, a single check size of about 1 arc deg, or a little smaller, such as about 50′, is sufficient. There is no need to use larger checks for children; since they can fixate properly to the stimuli and also their visual systems are mature enough to use the same size stimuli as adults [2].

3. ISCEV standard stimuli for clinical visual evoked potentials

International society for clinical electrophysiology of vision (ISCEV) has proposed a subset of stimulus and recording conditions which provide useful clinical information and can be implemented in most clinical laboratories. This subset of stimulus consists of: 1. PR-VEPs elicited by checkerboard stimuli with large 1° (i.e., 60 arc min) and small 0.25° (15 arc min) checks. 2. Pattern onset/offset VEPs elicited by checkerboard stimuli with large 1° (60 arc min) and small 0.25° (15 arc min) checks. 3. FVEP elicited by a brief luminance increment, which subtends a visual field of at least 20° and is presented in a dimly illuminated room [3].

Mean luminance required for the patterned stimuli is 50 cd/m^2 and the contrast between black and white regions should be more than 80% according to Michelson contrast. Michelson contrast is defined as

[1] In the expression 20/x vision, the numerator (20) is the distance in feet between the subject and presented chart and the denominator (x) represents the distance at which a person with 20/20 acuity would discern the same optotype. Thus, 20/40 means that a person with 20/20 vision would discern the same optotype from 40 feet away. In other words, the person possesses half the spatial resolution and needs twice the size to discern the optotype.

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