A fiber optic-based detector for behavioral eyeblink measurement in a MRI environment

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Synopsis

We previously described a reliable system to control the timing of multiple stimuli and to detect behavioral responses in fMRI studies of learning in animals. Here we report a modification to the system. The modified system uses a fiber-optic cable to avoid the interference often associated with the application of pulsed gradients during MR imaging, especially EPI. Comparison of the original and modified detection setups is demonstrated with behavioral measurements on awake, behaving rabbits in a MRI environment.

Introduction

We previously reported the design of a system for stimulus generation in behavioral studies, as well as a MR-compatible infrared (IR) reflectance detector to measure eyeblink or nictitating membrane (NM) responses (1). Although the whole system functions well in a MR imaging environment, one drawback of the original detector is that significant interference currents are induced in the detection circuit during application of pulsed gradients. Indeed, the voltage changes produced by these currents are often higher than those produced by the eyeblink or NM responses. Low-pass filtering can partially remove these artifacts at the risk of attenuating the eyeblink signal and obscuring small responses, making accurate quantitation of behavioral changes more difficult. In order to overcome these problems, we modified the system with improved opto-electronic components and a new detection setup that avoids the problems associated with the pulsed gradients.

Methods

The new detection scheme uses a fiber-optic cable (RoMack, Inc., Williamsburg, VA) to deliver IR light to the eye and collect the reflected signal, while the detector is placed far away from interfering magnetic fields (Fig. 1). The cable (3 mm diameter, 4 m length) consists of a bundle of 19 multi-mode optical fibers, each with a core diameter of 200 µm. The fiber bundle is bifurcated into 9- and 10-fiber segments. Nine of the fibers deliver IR light to the eye, while the remaining ten collect light reflected from the cornea, delivering it to the detector. Fig. 2 shows the detector circuit built for the system. The circuit incorporates into an amplifier composed of two OP ICs (UA741CN) a pair of opto-electronic components. A fiber optic GaAlAs LED (Optek Technologies, Inc. model OPF471A, Carrollton, TX) was selected as a photon transmitter and a fiber optic PIN photodiode (Optek Technologies, Inc. model OPF371A, Carrollton, TX), as a photon sensor. The LED and the photodiode can be surface-mounted on a printed circuit board, and interface easily with multimode optical fibers by means of standard SMA-905 connectors. Typical radiant power of the LED is 29 µW at a wavelength of ~850 nm with a forward current of 100 mA. In addition to its high sensitivity, the photodiode is characterized by a low dark current (typically 0.1 nA at V$_{th}$ = 5V), which leads to a very low baseline noise level.

We tested our modified detection setup in conscious, adult Dutch-Belted rabbits, using a short (100 ms), 3 psi airpuff to elicit an eyeblink response. All tests were performed in a GE/Bruker 4.7T imaging spectrometer in the presence of gradient pulses from a ssEPI pulse sequence, as described in (2). The eyeblink or NM responses were recorded and analyzed as described previously (1).

Results and Discussion

The high photon reception efficiency and low noise of the new photodiode allow the fiber-optic cable to be placed as far as 10 mm away from the cornea while still retaining good sensitivity.

Fig. 3 illustrates a comparison of the behavioral eyeblink responses recorded with the original and modified detection setups during fMRI data acquisition. Figs. 3a and 3b show the raw and low-pass filtered eyeblink responses, respectively, recorded with the original system. Note the large spikes superimposed on the signal in Fig 3a, which are induced by gradient pulses during imaging. Low pass filtering (Fig. 3b) only partially removes these artifacts. In contrast, the raw signal recorded with the modified detection setup is completely free from pulsed gradient artifacts, and displays substantially improved signal-to-noise characteristics.

Conclusion

We have shown that the detection setup modified by using fiber optic cable completely eliminates the interference often associated with gradient pulses during MR imaging. High sensitivity and low-noise of the PIN photodiode used in this system allow the fiber to be placed a comfortable distance from the eye, and allow the recording of clean behavioral responses in animals.

References


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