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Research Report

# Membrane properties and synaptic connectivity of fast-spiking interneurons in rat ventral striatum

*Stefano Taverna*[a,b], *Barbara Canciani*[b], *Cyriel M.A. Pennartz*[a,c,*]

[a]*Graduate School Neurosciences Amsterdam, The Netherlands*
[b]*Vrije Universiteit Medical Center, Department of Anatomy, P.O. Box 7057, MF-G102, 1007 MC, Amsterdam, The Netherlands*
[c]*University of Amsterdam, Swammerdam Institute for Life Sciences, Center for Neuroscience, Department of Animal Physiology and Cognitive Neuroscience, Amsterdam, The Netherlands*

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ABSTRACT

*In vitro* patch-clamp recordings were made to study the membrane properties and synaptic connectivity of fast-spiking interneurons in rat ventral striatum. Using a whole-cell configuration in acutely prepared slices, fast-spiking interneurons were recognized based on their firing properties and their morphological phenotype was confirmed by immunocytochemistry. Membrane properties of fast-spiking interneurons were distinguished from those of medium-sized spiny neurons by their more depolarized resting membrane potential, lower action potential amplitude and shorter half-width, short spike repolarization time and deep spike afterhyperpolarization. Firing patterns of interneurons could be subdivided in a bursting and non-bursting mode. Simultaneous dual whole-cell recordings revealed a high degree of connectivity of fast-spiking interneurons to medium-sized spiny neurons via unidirectional synapses. Burst firing in fast-spiking interneurons that were presynaptic to medium-sized spiny neurons resulted in barrages of postsynaptic potentials showing an initial amplitude increment, rapidly followed by a decrement. In conclusion, ventral striatal fast-spiking interneurons can be clearly distinguished from medium-sized spiny neurons by their membrane properties and their firing patterns can be subdivided in bursting and non-bursting modes. Their synaptic connectivity to medium-sized spiny neurons is unidirectional and characterized by frequency-dependent, dynamic changes in postsynaptic amplitude.
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## 1. Introduction

Fast-spiking interneurons (FSIs) constitute a class of interneurons of the ventral striatum (VS), a component of the striatum that plays a role in expressing and adjusting goal-directed and emotional behaviour (Mogenson et al., 1980; Pennartz et al., 1994; Cardinal et al., 2002; Carelli, 2002; Nicola et al., 2004a,b). FSIs contain aspiny dendrites, emit axon collaterals that spread locally but may also reach relatively distant subregions of the striatum, and express the calcium-buffering protein parvalbumin (PV; Kawaguchi 1993; Kawaguchi et al., 1995). Striatal FSIs are thought to exert inhibitory

* *Corresponding author*. Graduate School of Neurosciences Amsterdam, University of Amsterdam, Faculty of Science, Swammerdam Institute for Life Sciences, P.O. Box 94084, Kruislaan 320, 1090 GB, Amsterdam, The Netherlands. Fax: +31 20 525 7709.
E-mail address: pennartz@science.uva.nl (C.M.A. Pennartz).

*Abbreviations:* AHP, afterhyperpolarization; dPSP, depolarizing postsynaptic potential; FSI, fast-spiking interneuron; MSN, medium-sized spiny neuron; NGS, normal goat serum; PV, parvalbumin; TBS, Tris buffer solution; VS, ventral striatum

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control over the excitability of the principal cells of the striatum, i.e. medium-sized spiny neurons (MSNs; Kita et al., 1990; Pennartz and Kitai, 1991; Kita, 1996; Plenz and Kitai, 1998; Koos and Tepper, 1999; Koos et al., 2004). Patch-clamp studies in the dorsal striatum have shown that FSIs are characterized by 'fast' (i.e. short-lasting) action potentials discharged at high maximal rates (~200 Hz), prominent frequency accommodation when moderately depolarized, a relatively large spike afterhyperpolarization (AHP) and subthreshold oscillations occurring at a frequency of ~40 Hz (Kawaguchi, 1993; Koos and Tepper, 1999). Dual-cell recordings in cultured (Plenz and Kitai, 1998) and acutely prepared striatal slices (Koos and Tepper, 1999, 2002; Koos et al., 2004) presented evidence for $GABA_A$ receptor mediated inhibition by FSIs onto MSNs. *In vitro*, this inhibition is expressed by way of blocking or delaying postsynaptic firing of action potentials (Koos and Tepper, 1999). An additional type of interaction, which has been indicated by recordings in hippocampus but has not been

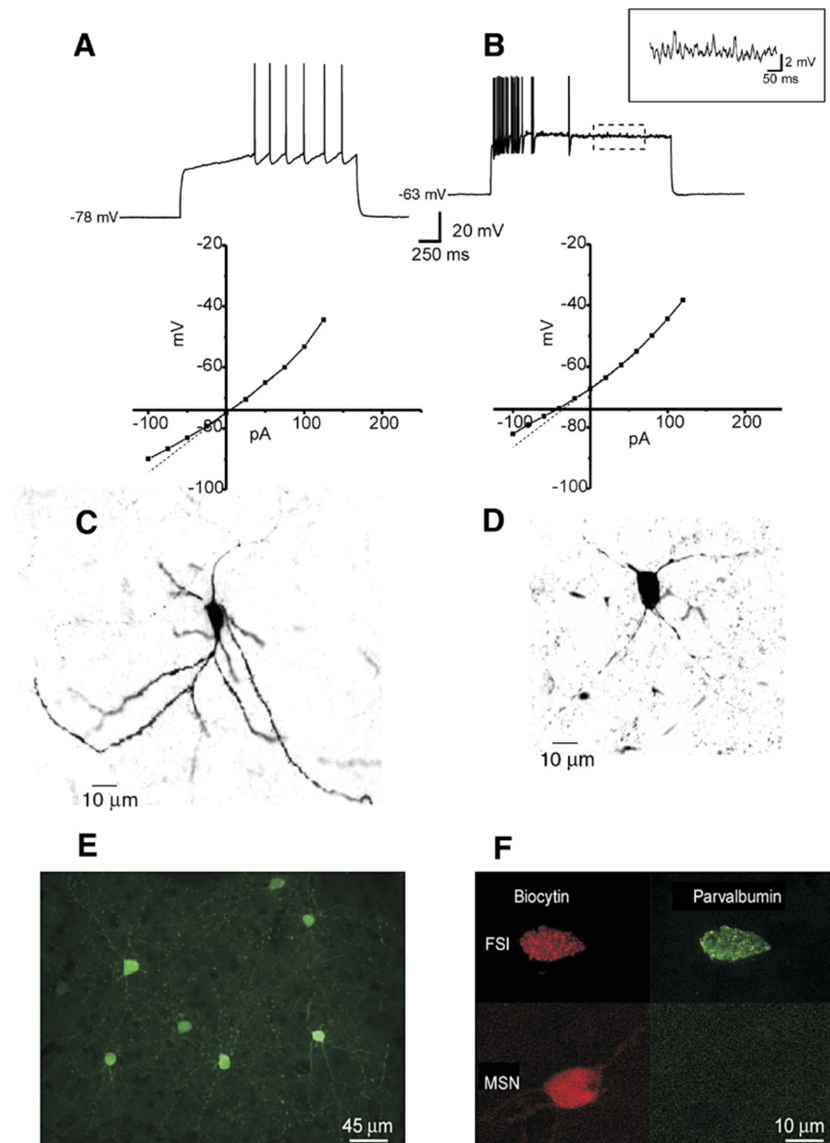


**Fig. 1 – Electrophysiological and anatomical properties of medium-sized spiny neurons (MSNs) and fast-spiking interneurons (FSIs). (A, B) Top, examples of current clamp recordings of MSN (left) and FSI (right) firing patterns in response to injection of a current pulse (100 pA, 2 s). Resting membrane potentials were −78 mV for MSN and −63 mV for FSI. Inset: magnification of subthreshold membrane potential oscillations elicited by current injection in FSIs. Bottom, current–voltage plots pertaining to a MSN (left) and FSI (right). Inward rectification at negative voltage levels is visible as a deviation from the linearly extrapolated portion of the curve (dotted line). (C) Example of a MSN filled with biocytin via the recording pipette and stained with DAB-nickel. Note the presence of dendritic spines. (D) FSI visualized by incubation with anti-parvalbumin antibody and staining with DAB-nickel. Four primary non-spiny dendrites are visible. (E) Fluorescent image of FSIs previously incubated with anti-PV antibody and streptavidin–Alexa 594 conjugate, (F) Double staining for biocytin and PV. Both FSIs and MSNs were positive to biocytin staining, whereas only FSIs were also positive to PV.**

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