Preservers of matrix pairs with a fixed inner product value

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Let $\mathcal{V}$ be the set of $n \times n$ hermitian matrices, the set of $n \times n$ symmetric matrices, the set of all effects, or the set of all projections of rank one. Let $c$ be a real number. We characterize bijective maps $\phi : \mathcal{V} \to \mathcal{V}$ satisfying $\text{tr} (AB) = c \iff \text{tr} (\phi(A)\phi(B)) = c$ with some additional restrictions on $c$, depending on the underlying set of matrices.