Summary
In current work we study the active maintenance of visual information in working memory and its effect on visual processing and attention. Recent investigations [1] have shown that humans have the ability to maintain a number of visual objects in visual working memory. A remarkable characteristic of this finding is that the number of objects that can be maintained in working memory without interference (i.e., loss of information) is limited (to about four), but the number of object features (e.g., color, form, location) is unlimited for each of the objects. Functional neuroimaging studies [2] have shown that in particular ventral prefrontal cortex (PFC) is involved in the maintenance of information in visual working memory. (In contrast with dorsal PFC, which appears to be involved in operations that manipulate the information maintained in visual working memory.) Furthermore, the neuroimaging studies did not reveal a distinction between spatial information and object (feature) information within ventral PFC.

In line with these observations, we present a model of visual working memory. The model is based on a neural 'blackboard' architecture that we used in our simulation of object-based attention in the visual cortex [3]. In the visual cortex, objects are identified through a feedforward network of areas, going from the primary visual cortex to the higher areas in the temporal cortex. In this network, retinotopic representation is gradually transformed into a location-invariant identity (e.g., shape, color) representation. Similarly, location information is processed in networks that start at the primary visual cortex. These networks transform retinotopic information into location representations related to movements of different body parts. In object-based attention, an object is selected as a target, and a feedback process is initiated in the networks that produce object identification. This feedback process carries information about the identity of the object to the lower areas in the visual cortex (i.e., areas in between the primary visual cortex and the higher-level identification areas). The feedback process interacts in these areas with the feedforward process described above. This interaction results in the enhanced activation of target representations in these areas, which results in the selection of target-related location information [3]. The representations in these lower 'in-between' areas consist of conjunctions of (partial) identity information and location information. This is a direct consequence of the fact that these areas gradually transform the retinotopic information in the primary visual cortex into identity-based information. By means of the interaction process described above, information about the location of an identified object can be recovered, even though that information was lost at the level of object identification. In a converse manner, the selection of a location in the 'in-between' areas can be used to select the information about the identity of an object, which will result in the identification of the object on the given location. In computational terms, the 'in-between' areas provide a ‘blackboard’ architecture because they link different ‘processors’ to one another [4]. The ‘processors’ in this case are networks for object identification (e.g., shape, color) and networks for location representation. The blackboard serves to unify (bind) the information processed in each of the specialized processors.

In current work, we develop a similar architecture for the maintenance of information in visual working memory. In this model, the nature of the representations in the ventral

PFC is similar to the nature of the representations in the 'in-between' areas of the visual (temporal) cortex described above. In the model, the 'in-between' areas in the visual cortex project to the ventral PFC. In turn, the ventral PFC is connected to the higher-level areas in the visual cortex in which (location-invariant) object identity and location information is processed and represented. When a display of objects is processed in the visual cortex, the object representations in the ventral PFC are activated as well. In the model, we assume that neural activation in ventral PFC consists of reverberating activity. In this way, information about the objects in the visual display can be maintained. The nature of the representations in ventral PFC and the connections with the higher-level areas in the visual cortex produces the behavioral effects described above. As in the 'in-between' areas in the visual cortex, the representations in ventral PFC consist of conjunctions of location and (partial) identity (object-feature) representations. When too many objects are present in a display, their representations in ventral PFC interfere, which results in loss of information. This interference results in a limitation of the number of objects that can be maintained in working memory. However, because the ventral PFC is connected to the 'identity' levels in the visual cortex, the number of features for each object is unlimited. The blackboard architecture of ventral PFC results in a unification (binding) of the feature representations of the objects maintained in memory, similar to the blackboard architecture in the visual cortex. In this way, all features of an object can be maintained in working memory as long as the representations of the object in ventral PFC do not interfere.

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