Multisensory Integration: A Functional Role for Inter-Area Synchronization?

It has been suggested that synchronization of neural activity in distinct areas of the brain is important in the 'perceptual binding' of the various features relating to a specific object. A recent study has provided new evidence that inter-area synchronization is important in multisensory integration.

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Research during the past decades has provided striking evidence that sensory modalities do not process their input independently from other sensory modalities — in a strict 'modular' fashion — but rather that sensory representations in one modality interact with those in others [1]. For example, in the McGurk effect subjects are presented with the auditory stream of a spoken syllable and a video of lip-movements pronouncing a different syllable. Under certain constraints the observer perceives a syllable that is phonologically somewhat intermediate between the visual and auditory input [2]. On the neurobiological level, numerous studies have found interactive effects of multimodal stimulation at the level of polysensory receptive fields in higher-level multisensory areas [3,4], and also influences of stimuli presented in one modality on activity in 'unisensory areas' of another modality [5]. This has raised the question of whether multisensory integration may result from lateral interactions between unisensory areas of the involved modalities, or whether the interaction is primarily achieved in higher-level sensory cortices and then eventually fed back to the lower-level unisensory areas [1,6].

A similar question has been raised in the context of object recognition and the binding problem in the visual domain [7,8] — the problem of how feature information apparently processed in different cortical areas, such as colour, form and motion, are 'bound' to the unique object to which they relate in the real world. One hypothesis has suggested that such binding of different aspects of a stimulus into an object representation might be achieved by flexible synchronization of distributed neuronal representations belonging to the same object [7], while others have emphasized the role of convergent feedforward projections [8].

In their study published recently in *Current Biology*, Maier *et al.* [9] have provided ample evidence for inter-areal synchronization during audio-visual integration of looming signals in monkeys. They investigated coupling between the lateral auditory belt region and the superior temporal sulcus (STS) under various combinations of auditorily and visually presented looming and receding signals. Receding signals mimic disappearing objects, while looming signals mimic approaching objects, and the latter are therefore considered to be ecologically more relevant and are perceived with greater saliency. The authors have recently demonstrated that the perception of looming signals in particular is enhanced greatly when they are presented multimodally [10], making them attractive for studying the neural basis of multisensory integration. In their new study [9], they report enhanced oscillatory synchrony in the gamma-band (60–80 Hz) between the lateral belt region and STS when a monkey perceives congruent audio-visual looming signals, and strongly reduced coherence when they perceived either incongruent audio-visual signals or purely auditory or visual signals. This follows the behaviourally observed saliency pattern and, importantly, is at least not consistently reflected in the amplitudes of neural responses in the respective sensory cortices.

How can one interpret this result in the context of theories on inter-area synchronization on the one hand, and mechanisms underlying multisensory integration on the other hand? While STS is known as a core multisensory area, with receptive fields sensitive to stimulation from different modalities, it also contains neurons that are primarily driven by visual input [11], and from the data reported by Maier *et al.* [9] it appears as though they have indeed recorded from neurons which are predominantly driven by visual input (with only little responsiveness to auditory stimulation). Thus, while recording from a classical unisensory and a classical multisensory area, Maier *et al.* [9] have investigated coupling between predominantly auditory and predominantly visual neurons.

What might be achieved by such oscillatory coupling between two processing streams on a functional level? In the work of Maier *et al.* [9], the synchrony depended strongly on the congruency between auditory and visual information, and it may therefore be tempting to interpret their finding in the context of the temporal correlation hypothesis of perceptual binding. Several studies have shown that, when different aspects of a visual object are integrated into a coherent percept, this state is characterized by enhanced neuronal synchrony amongst the involved neuronal populations [12]. The authors, however, do not interpret their results in terms of this theory, for good reasons: The stimuli used in the two audio-visual conditions they compared are rather different. In case of the congruent condition, auditory and visual stimuli were both highly salient looming stimuli, while in the incongruent condition the visual stimulus was a less salient receding stimulus, inducing weaker neuronal responses and resulting in fundamentally different timecourses of the two stimuli (auditory was also looming in this condition). Importantly, the authors carried out several crucial tests which render the possibility unlikely that the observed coherence in the congruent condition simply results from the common input to the two areas in the form of the nonstationary stimulus. Nevertheless, it cannot be excluded that factors other than perceived perceptual congruency — basic physical properties and saliency of the stimulus — may influence the strength of the observed coherence, and therefore an interpretation of the differential synchrony in light of the 'binding by synchronization' hypothesis at this stage remains somewhat ambiguous.

Rather, Maier *et al.* [9] focus on another idea for the role of neural synchrony, which has become more popular in recent years [13,14], while not being mutually exclusive with the idea of binding by synchrony. When two neuronal populations are synchronized and provide convergent input to downstream neurons, this results in a larger depolarisation of those postsynaptic neurons, and hence enhanced activation of later processing stages [15]. In a similar vein, when two areas of the brain are synchronized, it is ensured that both neuronal membranes are at a mutually optimal excitabilty state to receive input or send output — for a detailed illustration of these ideas see [14], and see [16] for a related effect — and this should lead to more efficient transmission of neural activity. In that respect, the reported enhanced synchrony of high-frequency oscillations between auditory and visual cortex (to audiovisual looming stimuli) may explain the behavioural benefits of multimodally presented audio-visual looming stimuli against incongruent or purely visual or auditory looming signals.

The question remains, how is this synchrony established? It is a well known property of oscillators that these easily adjust their phase even in the presence of only relatively weak coupling between them [17] and the STS is connected with the auditory belt region. So, is it all about facilitation of information transmission, or might the role of synchrony between the two processing streams be more generic — for integrating their sensory representations into a common percept?

At this point, this remains pure speculation. Not much is currently known about how multisensory representations are formed from unimodal inputs. One computational model [18] assumes convergent projections of unisensory areas onto a multimodal map which will then combine its inputs by recursive activations between the multisensory area and the unisensory areas and can thereby reproduce important findings from psychophysical research [19]. This particular model explicitly does not make any assumptions about the relative timing of the respective inputs and outputs. Irrespective of the details of the model, however, the existence of such recursive modes of processing between multisensory and unisensory areas is quite likely given the findings in the literature [1] and it would be of interest to investigate whether selective temporal coordination of the inputs — as observed by Maier *et al.* [9] — is correlated with the efficiency of how inputs are combined in the working brain and may therefore provide a solution to the "correspondence problem" [19]. Future experiments should investigate whether synchrony between two sensory processing streams covaries with behavioural measures of fusion between the sensory representations and, for example, whether this can be flexibly established depending on the task requirements or by using bistable stimuli that sometimes fuse and sometimes do not — under identical physical (stimulus) conditions.

The remarkable finding from Maier *et al.* [9] is that they establish the existence of stimulus specific synchronization between auditory and visual brain areas and that synchrony seems to correspond with a behavioural effect of audio-visual integration [10].

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HIV-1 Infection: Going Nuclear with TNPO3/Transportin-SR2 and Integrase

Factors necessary for HIV-1 nuclear import have been sought for many years. Recent reports suggest that TNPO3/Transportin-SR2 binds to HIV-1 integrase and is required for HIV-1 infection of interphase cells.

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Everyone agrees that HIV-1 infects non-dividing cells [1], yet viral factors and host factors that promote HIV-1 nuclear import have been very difficult to pin down [2]. Recent studies now show that TNPO3/Transportin-SR2 plays a role in HIV-1 replication [3,4] and, via an interaction with HIV-1 integrase, promotes the nuclear import of HIV-1 [4]. The discovery of a host