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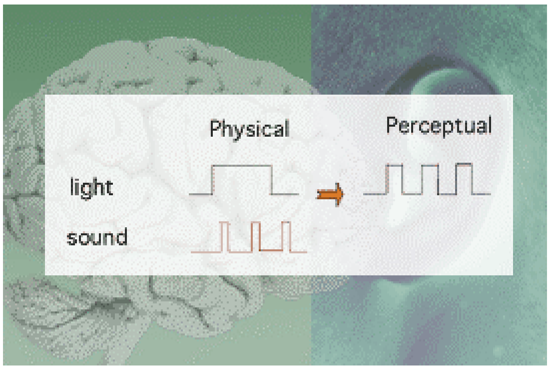

Integration in the brain

- *The Subconscious Alteration of Visual Perception by Cross-Modal Integration*

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http://psych.pomona.edu/scr/LN_Oct02_IntegrBrain.htm

It is clear that the information processed by the different sensory modalities are integrated into a coherent multisensory percept by the brain. However, it is not known how, nor at what level of processing, nor where in the brain this integration takes place. As a result, it is also not clear whether the combination of signals from different modalities occurs prior to or following conscious sensory processing. Artificially imposing conflict between the information conveyed by different modalities (which are, under normal circumstances, often consistent) has proved to be a useful way of studying cross-modal interactions. This paradigm may also be useful for gaining insight into the processing stages of multi-sensory integration and their relationship with conscious awareness.

Events in the physical environment have characteristic signatures that the human brain has evolved to perceive and discriminate. These signatures are often in the form of multiple types of physical energy, ranging from electromagnetic radiation (light) to specific chemicals to mechanical energy, and are discriminated through the presence of different sensory modalities that are specially attuned to these "stimuli". For example, the visual system is specialized for perceiving electromagnetic radiation, hearing is specialized for perceiving sound waves, touch perceives mechanical deformations of the skin, and, taste and smell process specific concentrations of different combinations of chemicals. Sensory processing in the brain is believed to be highly modular, divided into separate pathways for each sensory modality. However, our

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experience of the world clearly does not consist of a collection of separate sensations; rather, it is a multi-sensory, yet coherent, monolithic experience. This suggests that information from the various sensory modalities must be integrated at some level(s) in the brain. Various behavioral findings revealing the effect of one modality on another confirm this insight.

We have recently reported such a cross-modal effect. The "sound-induced illusory flash," or "illusory flash effect" for short, demonstrates that sound can radically change the phenomenological quality of the percept of a non-ambiguous visual stimulus: When a single brief visual flash is accompanied by multiple auditory beeps, the single flash is perceived as multiple flashes (click here for a QuickTime demo). Control conditions indicate that the illusory flash effect is indeed a perceptual illusion and is not due to the difficulty of the task, or some cognitive bias caused by sound. The temporal tuning of this effect was also measured by varying the relative timing of the visual and auditory stimuli. The illusory flash effect declined from 70ms separation onwards, however, it occurred strongly so long as the beeps and flash were within approximately 100ms. The illusory double flash is perceptually very similar to a physical double flash. Furthermore, the illusion is not affected by the observer's knowledge about the physical stimulus, again confirming that the illusion is not due to cognitive influences.

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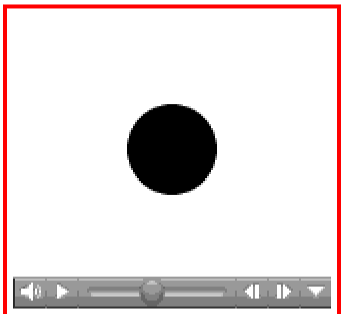

Image from demo

It is also noteworthy that the percept of the illusion is not accompanied by a perception of conflicting signals. Pairing of the one flash with two beeps does not lead to a perception of conflict, but rather a coherent perception of (the illusory) double flash. In other words, the subjects do not experience two separate sensations, one corresponding to two events (induced by the two sounds) and the other to one event (induced by the single flash). Thus, there is no sense of conflict prior to or simultaneous with the perception of the illusion. This absence of conflict may suggest that the integration of the signals from the two modalities (two beeps and one flash) does not occur post-consciously. In other words, consciousness does not have access to processing that may occur within individual sensory pathways before integration; it is only *after* the signals from the two modalities are combined that the percept becomes conscious. If this interpretation is correct, it would implicate one of the two following scenarios: either multi-sensory integration occurs at

It seems the multi-sensory integration occurs at an early perceptual stage

an early perceptual stage, or conscious perception occurs at a rather late stage. Existing evidence appears to favor the former.

The processing stages or the brain areas in which the signals from the different modalities are integrated are still an active area of research. We used the illusory flash effect to probe this question. We recorded visual evoked brain potentials (VEPs) utilizing a framework based on the illusory flash effect in order to examine the locus in the brain (sub-cortical regions, visual cortical areas, or polysensory associative cortical areas) associated with alterations of visual perception by sound. Our previous psychophysical observation had shown that the illusory flash effect is significantly stronger in the periphery than in the fovea. In order to search for any physiological correlation with this perceptual effect, we recorded VEPs for flashes presented in the fovea and the periphery separately. The data indicate extensive and early modulation of VEPs by sound in the illusion trials (the majority of the peripheral trials), in contrast to the lack of modulation of VEPs by sound in the non-illusion trials (the majority of the foveal trials). We also compared the time-frequency amplitudes of the illusion trials in the periphery with the no-illusion trials in the periphery, and found significant auditory-visual interactions only in the illusion trials. These results altogether provide a clear neurophysiological correlate for the perception of the illusory flash. In the no-illusion trials, a similar pattern of modulation of visual activity by sound was present, although not significant. This suggests that the perception of illusory double flash is only possible when the modulated visual activity by sound exceeds a 'perception threshold' for being registered as a flash percept. Otherwise the modulation is unable to trigger awareness.

The illusory flash effect is significantly stronger in the periphery than in the fovea

Modulations of VEPs by sound occurred as early as ~140 ms after the onset of the second beep (or 170 ms after the onset of the flash). Considering that event-related potentials prior to 200ms after a stimulus are believed to be due to the activity in the modality-specific pathways, these modulations appear to occur in the visual pathway. Most interesting was the finding that similar modulations were induced by sound as by an additional physical flash. The comparison of the difference waves revealed a striking similarity between the activity associated with an illusory second flash and that of a physical second flash. This similarity suggests that similar brain mechanisms underlie the illusory and physical second flash. Because the evoked response to a physical flash involves activity in the visual cortex, this implies that the representation of the illusory flash also involves the activity in the visual cortex.

It is suggested that similar brain mechanisms underlie the illusory and physical second flash

The results of this study suggest that sound affects processing at the level of the "visual" cortex. These findings contradict a long-standing modular view of perceptual processing. Several recent studies utilizing functional imaging, transcranial magnetic stimulation (TMS), and magnetoencephalography (MEG) also have provided evidence that areas that have traditionally been viewed as modality-specific are actually modulated by signals from other modalities. Interestingly, recent anatomical studies suggest a cortical pathway that may underlie the early cross-modal modulations in visual cortical areas indicated in the aforementioned VEP data. Two very recent monkey neuroanatomical studies report direct projections from auditory cortex to primary visual cortex. Intriguingly, both studies report projections only to the peripheral representations in primary visual cortex (V1) and not the foveal representations, consistent with the differential effects between the fovea and periphery that we have observed in our psychophysical and VEP studies. Considering that previous studies have suggested that conscious perception occurs at a stage later than V1, the possibility of the visual perception being affected by sound already at the level of V1 would be consistent with our earlier speculation that the auditory-visual integration observed in illusory flash effect occurs prior to conscious awareness.

Suggested links

Homepage of Dr. Shams

- Demo of the phenomenon (requires QuickTime player)
- "Did you see what you heard?" on The Scientist (bottom of page)
- Caltech Media Relations

The McGurk effect - download demo

- Article on American Scientist
- Demo on Prof. Arnte Maasø's homepage
- Article and explanations at "Talking Heads" (with links)
- Google search for "McGurk effect"

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