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About exact temporal precision and slow information integration

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Abstract

It is often believed that the integration of information over time is similar at the unconscious and conscious levels. Here we will present four different studies suggesting that the time resolution of unconscious information processing is much better than previously believed, but also that information is not integrated over such short intervals like it is at larger times. Even though information is unconsciously processed in an almost continuous fashion, it is its time consuming integration that leads to a conscious and meaningful percept. We show how neuronal correlates, like e.g., the phase of neuronal oscillations, are associated with this transformation.

Keywords: Temporal window; Subjective window; Functional window; Implicit processing; Ambiguous figures; Multisensory integration; Neuronal oscillations

1. Introduction

We think about time as continuously flowing, as if information is processed without interruptions. However, it takes time to integrate information defining different temporal windows (van Wassenhove, 2009; Wittmann, 2009). Typically the functional window corresponds to the lowest limit of discrimination between successive events. In the

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subjective window, on the other hand, successive events are clearly distinguished in time but are all present simultaneously in mind. For example, when hearing a melody, the notes just past and the notes to come are all present in mind, even though they are known to be past or present. This is what makes it possible to have a sense of melody (Husserl, 1928). It is usually believed that these time windows are shared by both conscious and unconscious processes. However, this leads to difficulties. For example, if successive events are processed as co-temporal in the functional windows, this would imply a succession of snapshots at relatively large intervals of at least 30-50 ms long and even longer windows in the case of multisensory information. This seems in contradiction with our sense of time continuity, since it is as if time stops within functional windows. Second, it is unclear how different types of information are integrated within functional windows, whether unimodal or multisensory. Integration of features itself takes some time. Are features, displayed within a functional window, automatically integrated? What kind of integration does the functional window entail? To which amount do the functional and subjective windows correspond to neuronal constraints? If they do, can we find the neuronal correlates of the temporal windows?

Here we present different approaches that address these questions aimed at leading to a coherent picture. Taking different approaches, both Anne Giersch and Michael Herzog show that the temporal resolution of information processing is by far better than subjective experience suggest. Their results suggest the existence of automatic and unconscious information processing occurring in time intervals of <20 ms, and that this processing is dissociated from information integration associated with consciousness, like temporal order or feature integration. Consistent with these observations, Juergen Kornmeier provides electrophysiological evidence that disambiguation of ambiguous visual information takes roughly 40-60 ms but conscious perception of the disambiguated information needs about 500 ms. Finally, Virginie van Wassenhove uses auditory and visual stimulation to examine the neural correlates of temporal integration over 200-300 ms and of temporal order. Results from her group suggest that the encoding of event timing in the phase of neural oscillations linearly predicts conscious audiovisual simultaneity.

All in all, these four approaches suggest that implicit processing of information in time is both richer and less integrated than previously believed. We propose that implicit and explicit coding of information over time may serve different functions. The high temporal resolution of information coding should not confuse events with each other, and allow us to process information in an almost continuous way. On the other hand, relating events with each other may not be carried out automatically. The implicit processing of events over time does not correspond to our subjective perception of the world, which is much more stable and integrated. It is the possibility to order and integrate events that allow us to make our conscious environment meaningful, e.g., to hear a melody rather than unrelated notes. These mechanisms of integration would transform unconscious and meaningless bits of information into an integrated conscious percept. And it is this transformation that is sub-tended by neural correlates, like the phase of neuronal oscillations. The following paragraphs detail each of the four approaches.

2. The functional window and the coding of temporal order: What patients with schizophrenia tell us - Anne Giersch

Exploring information processing over time in patients with schizophrenia can help to better understand their thought disorders, e.g., thought disorganization and a disordered sense of time continuity. It can also question the normal functioning of the brain.

Experimentally, patients with schizophrenia are impaired in discriminating between simultaneous and asynchronous events, leading to enlarged windows of temporal simultaneity (Giersch et al., 2009). This led us to question whether they process all events within functional windows as co-temporal. During the tasks, subjects decided whether two squares were displayed simultaneously or asynchronously, and gave their response by hitting a left or right response key. We repeatedly showed that when stimuli are asynchronous and displayed on opposite sides, manual responses are biased to the side of either the first or second stimulus (Lalanne et al., 2012a,b). Such a bias allowed us to show that both patients and controls distinguish events in time at an implicit level even when explicitly judging such events to be synchronous. These results show that the temporal resolution of information coding is higher than was previously believed. In addition, patients and controls differed on the side of the bias. Controls were systematically biased to the side of the second stimulus, whereas patients were biased to the side of the first stimulus, but only at short asynchronies. These results show a dissociation between the implicit and explicit