

# Information integration without awareness

Liad Mudrik<sup>1\*</sup>, Nathan Faivre<sup>1\*</sup>, and Christof Koch<sup>1,2</sup>

<sup>1</sup> Division of Biology, California Institute of Technology, 1200 E California Blvd, Pasadena, CA 91125, USA

<sup>2</sup> Allen Institute for Brain Science, 551 North 34th Street Seattle, WA 98103, USA

**Information integration and consciousness are closely related, if not interdependent. But, what exactly is the nature of their relation? Which forms of integration require consciousness? Here, we examine the recent experimental literature with respect to perceptual and cognitive integration of spatiotemporal, multisensory, semantic, and novel information. We suggest that, whereas some integrative processes can occur without awareness, their scope is limited to smaller integration windows, to simpler associations, or to ones that were previously acquired consciously. This challenges previous claims that consciousness of some content is necessary for its integration; yet it also suggests that consciousness holds an enabling role in establishing integrative mechanisms that can later operate unconsciously, and in allowing wider-range integration, over bigger semantic, spatiotemporal, and sensory integration windows.**

## Integration and consciousness: a redefinition of their possible relations

In the scientific study of consciousness, great emphasis is placed on integration (defined further below): it is held to go hand in hand with consciousness, reflecting both the unified and holistic nature of conscious experience and the hypothesis that consciousness is needed for integration to occur (see [Table 1](#) for quotes from influential publications in the field). Traces for this potential close tie date back at least to the writings of Descartes [1], Kant [2], or James [3] ([Table 1](#)). This long tradition of coupling consciousness with integration has a strong influence on current thinking. In this review, the main statements relating consciousness and integration are examined, and restated in a way that differentiates between several types of integration (i.e., spatiotemporal, multisensory, semantic integration, and integration of novel information). Review of existing empirical data (especially in the visual domain, because most studies focus on visual awareness\*) suggests that there is no absolute dependency of integration on consciousness. Rather, the more complex or novel the stimuli, the more likely consciousness will be needed for integration to occur.

Corresponding authors: Mudrik, L. ([liadmu@gmail.com](mailto:liadmu@gmail.com)); Koch, C. ([christofk@alleninstitute.org](mailto:christofk@alleninstitute.org)).

Keywords: consciousness; integration; unconscious processing; multisensory integration; integration windows; global neural workspace; integrated information theory.  
\*These authors contributed equally to this article.

<sup>†</sup>In this paper, we use the terms 'awareness' and 'consciousness' interchangeably.

1364-6613/

© 2014 Elsevier Ltd. All rights reserved. <http://dx.doi.org/10.1016/j.tics.2014.04.009>

## What precisely is meant by integration?

A phenomenological definition of integration is the combining of different features (e.g., parts of an object that are detected independently of each other [4]) into a unified percept (the binding problem [5]): for example, having a single experience of a black line rather than having two experiences, one of the color black and the other of a line. A cognitive definition of integration is the generation of a nonperceptual, abstract representation by associating distinct signals into a new one (e.g., when comparing the semantic congruency of two items and determining that '2' and '4' are both even numbers, or when constructing a new meaning by integrating two words such as 'honey' and 'moon' into a new word, 'honeymoon'). A formal, mathematical definition of integrated information is information that a system has as a whole, above and beyond the information possessed by the union of its parts [6,7].

Given the massively recurrent architecture of the brain, all neural processes are likely to involve some level of integration. Here, we specifically address integrative processes in which two or more distinct stimuli, or stimuli

## Glossary

**Unconscious processing:** encoding of stimuli that remain below the threshold of awareness due to experimental or clinical conditions. That is, the stimulus is not consciously seen or heard or otherwise experienced. In this review, we focus on unconscious rather than implicit integration, in which the stimuli are perceived consciously but integrated without awareness of doing so. An example of such implicit integration is implicit sequence learning [92], where subjects implicitly integrate sequences of supraliminal stimuli, without explicitly declaring noticing such sequences.

**Integrated information theory (IIT):** identifies consciousness with information integration, so that the level of consciousness of a system is equivalent to its ability to integrate information over and above the information that is integrated by the union of its parts [93,94]. Importantly, however, in its current form, IIT does not include behavioral predictions about conscious versus unconscious processing [14].

**Global neural workspace (GNW) theory:** argues [12,25] that consciousness occurs when top-down attentional amplification mobilizes frontoparietal networks broadcasting neural signals throughout the brain. This makes those neural signals available to a variety of processes, including perceptual categorization, long-term memorization, linguistic processing evaluation, and intentional action. The theory draws from the Global Access Hypothesis in cognitive science [9,21], yet goes further in suggesting specific neural mechanisms that subserve global access.

**Integration windows:** the process of forming a unified representation from two or more features that are separated in space, in time, semantically, or in two different sensory modalities. The maximal distance between the integrated features defines the size of the integration window: for spatial integration windows (SIW), this distance refers to the actual distance in space between the integrated features. For temporal integration windows (TIW), it refers to the duration of the interval between the integrated events. For multisensory integration windows (MIW), it refers to the number of the integrated modalities, and for spatial processing integration windows (SPIW), it refers to the depth or level of complexity of semantic integration (see Box 1 for examples).

**Table 1. Consciousness and integration in selected influential publications**

Paper	Quote
Descartes, 1660 and 1664, respectively [1]	"[...] since our soul is not double, but one and indivisible, [...] the part of the body to which it is most immediately joined should also be single and not divided into a pair of similar parts"; AT III:124, CSMK 149, and "it is only the latter figures which should be taken to be the forms or images which the rational soul united to this machine will consider directly when it imagines some object or perceives it by the senses"; AT XI:176, CSM I:106
Kant, 1781 [2]	"[...] the unity that the object makes necessary for us can be nothing other than the formal unity of consciousness in the synthesis of the manifold presentations. When we have brought about the synthetic unity in the manifold of intuition—this is when we say we cognise the object"; A105
James, 1890 [3]	"our mental states are composite in structure, made up of smaller states conjoined", and "We cannot even [...] have two feelings in mind at once", p. 145 and p. 157, respectively.
Marcel, 1983 [17]	"Conscious perception requires a constructive act whereby perceptual hypotheses are matched against information recovered from records, and serves to structure and synthesize that information recovered from different domains. These processes are related to three aspects of phenomenal experience: awareness, unity of percepts, and selectivity", Abstract.
Crick and Koch, 1990 [88]	"Our experience of perceptual unity suggests that the brain in some way binds together, in a mutually coherent way, all those neurons actively responding to different aspects of a perceived object [...] [neurons in different areas] are 'bound' together to carry a common label identifying them as neurons that jointly generate the perception of that specific face", p. 269.
Singer, 1998 [90]	"In humans, only signals selected by attentional mechanisms reach the level of phenomenal awareness and only these selected signals can be integrated in episodic memories", p. 1830.
Tononi and Edelman, 1998 [91]	"Categorizations of causally unconnected parts of the world can be correlated and bound flexibly and dynamically together inside consciousness but not outside it", p. 247.
Damasio, 1999 [10]	"[...] a theory of consciousness should not be just a theory of how the brain creates integrated and unified mental scenes, although the production of integrated and unified mental scenes is an important aspect of consciousness, especially at its highest levels. Those scenes do not exist in a vacuum. I believe they are integrated and unified because of the singularity of the organism and for the benefit of that single organism. The mechanisms that prompt the integration and unification of the scene require an explanation", pp. 18–19.
Engel, Fries, König, Brecht, and Singer, 1999 [8]	"[...] awareness seems to presuppose the capacity for structured representation, that it, the ability to achieve coherence of the contents of mental states and to establish specific relationships between representational items".
Edelman and Tononi, 2000 [13]	"When we become aware of something [...] it is as if, suddenly, many different parts of our brain were privy of information that was previously confined to some specialized subsystem [...] the wide distribution of information is guaranteed mechanistically by thalamocortical and corticocortical reentry, which facilitates the interactions among distant regions of the brain", p. 148-149.
Kanwisher, 2001 [15]	"[...] in order for a focal neural representation to reach awareness it may have to be accessible to other parts of the brain [...] a conscious percept is not simply a disorganized soup of activated visual attributes, but rather a spatiotemporally structured representation in which visual attributes are associated with particular objects and events. The construction of a fully conscious percept may involve interactions between domain-specific systems for representing the contents of awareness (primarily in the ventral visual pathway) and domain-general systems (primarily in the dorsal pathway) for organizing those contents into structured percepts", p. 109.
Dehaene and Naccache, 2001 [12]	"[...] a distributed neural system or 'workspace' with long-distance connectivity that can potentially interconnect multiple specialized brain areas in a coordinated, though variable manner [...] The global interconnection of those five systems can explain the subjective unitary nature of consciousness and the feeling that conscious information can be manipulated mentally in a largely unconstrained fashion", pp. 13–14.
Varela, Lachaux, Rodriguez, and Martinerie, 2001 [18]	"[...] the large-scale integration of brain activity can be considered as the basis for the unity of mind familiar to us in everyday experience", p. 237.
Baars, 2002 [9]	"Unconscious input processing is limited to sensory regions [...] Consciousness is needed to integrate multiple sensory inputs, presumably by mobilizing specialized functions like syntax, semantics, high-level visual knowledge, problem solving and decision making", pp. 47–48.
Treisman, 2003 [5]	"Conscious access reflects binding. Conscious access in perception is always to bond objects and events [...] It [consciousness] combines information from many brain areas, and it binds that information to form integrated objects and events [...] Within this framework, binding is central to conscious experience", pp. 97–98.
Goodale, 2004 [89]	"The representations constructed by the ventral stream play an essential role in the identification of objects an enable us to classify objects and events, attach meaning and significance to them, and establish their causal relations", p. 1161.
Fahrenfort and Lamme, 2012 [11]	"A real perfect experiment would provide the neural mechanisms that explain functional properties of consciousness. Such mechanisms should be able to integrate contextual information across the visual field, making inferences about its input while resolving perceptual ambiguity. They should be able to dynamically group image elements together, creating perceptual unity and perceptual organization", p. 138.
Koch, 2012 [16]	"Conscious states [...] are highly integrated [...] Whatever information I am conscious of is wholly and completely present to my mind. Underlying this unity of consciousness is a multitude of casual interactions among the relevant parts of my brain. If areas of my brain become fragmented, disconnected, and balkanized, as occurs under anesthesia, consciousness fades", p. 125.

Download English Version:

<https://daneshyari.com/en/article/141467>

Download Persian Version:

<https://daneshyari.com/article/141467>

[Daneshyari.com](https://daneshyari.com)