COVERT ATTENTION AND MOTION PERCEPTION

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Abstract

Explicit perception requires attentional modulation of the stimulus signals, whether in motion or not. As the covert attentional process is relatively slow in comparison with specific encoding of the stimulus signals then certain dissociation between objective stimulus position and subjective representation of this position can be evidenced at the onset of stimulation. Several psychophysical phenomena support this notion. Yet the spatial perceived dissociation does not have an invariant value; with accumulating sensory input this value gradually diminishes. We therefore infer acceleration of signal processing for explicit perception right after the first instances of input signals from the stimulation. Perceptual acceleration is hypothesised to be a consequence of covert-attentional modulation of the following sensory signals by the attentional process that was initiated by the onset of a stimulus-event under consideration. As the very first signals do not have local precedence then both they may be absent from explicit perception and lag behind the processing of later arriving signals in terms of the speed with which respective explicit representation is established.

An increasing body of evidence supports the notion that explicit perception requires participation of attentional mechanisms in signal processing (Crick, 1984; He, Cavanagh, Intriligator, 1996; Logothetis, Leopold, Sheinberg, 1996; Simons, Levin, 1997; Enns, DiLollo, 2000; Rensink, 2000; Simons, 2000; Simons, Franconeri, Reimer, 2000; Driver et al., 2001; Scholl, 2001; Most et al., 2001). In addition to guaranteeing that stimuli become perceived at all, attentional modulation can also determine which way explicit perception emerges out of invariant physical stimulation in perceptually multistable displays (Sekuler, Ball, 1977; Cavanagh, 1992; Stelmach, Herdman, McNeil, 1994; Yantis, Gibson, 1994; Sekuler, 1995; Chun, Cavanagh, 1997; von Grünau, Bertone, Pakneshan, 1998). Specific processing of sensory signals at the stage of cortical encoding is faster than the process of covert directed attention that is evoked by the onset of a stimulus event (compare Purpura, 1970; Scheibel, 1981; Rolls, Tovee, 1994; Tovee, Rolls, 1994; Bachmann, 1984, 1999, and Eriksen, Collins, 1969; Nakayama, Mackeben, 189; Cheal, Lyon, Gottlob, 1994). It takes time for the attentional mechanism to maximise its facilitative modulating effect on specific encoding processes. When putting the above premises together we arrive at the conclusion that the spatiotemporal properties of explicit perception should be different between the conditions where the signals of a stimulus-event have been just onset and the conditions where these signals have been accumulating already for some time. In what follows let me present some phenomena of motion perception observed at the onset of visual events comprising of spatial translation of stimuli and suggest an explanation for the experimental phenomenology which is based on interaction of the faster encoding and slower attentional modulating mechanisms.

Motion phenomena involving objective-subjective dissociation

Fröhlich effect. When a moving object appears from behind a nontransparent occluder, its first explicitly visible position is shifted away from the objective position it first appeared in the direction of motion (Fröhlich, 1923; Müsseler, Aschersleben, 1998). This effect can be explained by the fact that the process of attentional modulation of the specific stimulus signals that carry information about its spatial position takes some time to become effective and therefore, at the moment when the modulating signals of the attentional mechanism arrive at the cortical sites of the encoding neurones, the characteristics of spatial position of the stimulus have changed, indicating an advanced position in space. As a consequence, the stimulus is first perceived at an advanced position from the location at the edge of the occluder from where the signals were first input into the processing system. This explanation can be valid on the account of poor spatial resolution of the attentional system. Empirical evidence from psychophysical research as well as neuroscientific data on the size of the receptive fields of nonspecific thalamic neurons that participate in directed cortical activation support this requirement (Steinman, Steinman, Lehmkuhle, 1995; Bachmann et al., 1999; Brooks, Jung, 1973; Gouras, Padmos – cited according to Bridgeman, 1980).

Tandem effect. When two spatially separated objects move through a horizontal window in the horizontal direction in close succession, however without being simultaneously exposed within the window (i.e., the inter-object distance is larger than the width of the window), then observers nevertheless perceive a pair of objects in the window, given optimal spatial and temporal parameters of stimulation; this so-called Tandem Effect implies compression of the inter-object distance in explicit perception (Kolbert, Müsseler, 1981, unpublished thesis; Müsseler, Neumann, 1992). According to the attentional explanation the secondly appearing object benefits from the attentional process that was initiated by the first appearing object and consequently its explicit perception becomes relatively accelerated. As a result, the visibility-related modulation of the specific trace of the first object is temporally associated with the faster-performed modulation of the specific signals of the second object and the objects become perceived simultaneously in the window.

The line-motion effect. When the stroboscopic display consists of a small dot (or disc, or square) as the first stimulus, followed by a simultaneously displayed line as the second stimulus (the imagery extension of the line crossing the first stimulus), then the line-motion illusion can be created (Hikosaka, Miyauchi, Shimojo, 1993, 1996; Shimojo et al., 1997). Given optimal stimulus onset asynchronies (SOAs), observers experience illusory motion from the locus of first stimulus along the line towards its far end. We can hypothesise that the process of attentional modulation that was evoked by the appearance of the first stimulus is temporally delayed and also involves a spatiotemporal gradient. The modulating signals in time become applied to progressively more spatially advanced signals representing the line-stimulus information. As a result, directly visible motion along the line is experienced.

The effect of overtaking. In a recent experiment (Bachmann, Oja, unpublished) we have utilised the display which was used earlier to study the flash-lag effect (Bachmann, Kalev, 1997). A reference stimulus, a vertical bar, translates continuously across the display screen along the horizontal path of motion. Another vertical bar (a replica of the reference stimulus) translates within a virtual window, the size of which is considerably smaller than the extent of motion of the reference stimulus. Otherwise the speed and direction of movement of the aperture line is identical to those of the reference line. Observers can adjust horizontal spatial separation of both lines, including adjustments that let the lines appear perceptually collinear at a prespecified location. With suitable speeds of motion and diameters of the window it is possible to find perceptual experience of overtaking: the aperture line that is initially (at the point of appearance) lagging behind the reference line in space appears to gradually catch up with the reference line and move past it. Actually, the lines are spaced invariantly in physical space, with aperture line slightly advanced in space from the position of collinearity. This illusion can be explained similarly to the explanations given to the above phenomena. The slow modulation process which is necessary for explicit representation becomes relatively faster, the later the moment when the signals of the moving stimuli are sampled. This results in visible acceleration of the movement of the aperture line along the path of motion. With continuously moving reference line at its more advanced spatial locations the modulation process has been already prepared by the temporally preceding samples of specific signals and the visual latency is the shortest possible. With aperture line that flashes only briefly and has just appeared (to disappear again), the time it takes for modulation to arrive at the specific encoding sites is relatively slow because there has not been a precedence of the local signals that would have prepared attentional modulation ahead in time. Thus, initially, the perceived position of the aperture line lags behind the perceived position of the reference line, the signals of which have already been modulated. The more time has passed from the moment of appearance of the aperture line, the higher the probability that the attentional mechanism has already taken its effect (having been evoked by the first instant of stimulus appearance). This means that the longer the aperture line has been in the view, the faster is the processing of its signals up to visible representation and, therefore, what is directly experienced is the on-line acceleration of motion of the aperture line. The exact form of the probability distribution for the time constant of completion of the attentional function remains to be ascertained in future research. At present and for the convenience one may use a normal distribution.

Flash-lag effect. If a visual (reference-) object is continuously moving in a given direction and another object (a target) is briefly flashed at a certain point of the trajectory of motion, then the target seems to lag behind the moving object, although they are physically aligned (Hecht, 1924; Nijhawan, 1994). The explanation for this effect is equivalent to the explanations suggested before. Let us suppose that a moving stimulus can be interpreted as a fast succession of an infinite number of different stimuli that are sampled by the visual system as if the replicas of the same stimulus. The spatial positions of exposure of these replicas are adjacent to each other and successive in time. One can regard each preceding instance of the stimulus replica as the input that had chance to initiate attentional modulation; the more there are the preceding replicas, the higher the probability that the impact of modulator has been maximised already. Thus with a stimulus in motion, the sampling of its specific signals becomes accelerated from the first moment of appearance of the stimulus event, until the speed of explicit perception becomes stabilised at a speed that is higher than the speed with which signals reach explicit representation initially, after their initial onset. This state of affairs defines the flash-lag effect – the apparent displacement of the continuously moving object ahead of the flashed object.

Generality of initial perceptual acceleration and "inner psychophysics"

We have reached the conclusion that the attentional account may help to explain a variety of perceptual phenomena involving motion and that the relative slowness of attentional modulation – which can be compensated by the precedence of spatially adjacent stimulation over its following successors when stimulation is temporally extended – can create perceptual dissociations at the onset of stimulation. It also follows that explicit perception undergoes initial acceleration after the very first moment the input signals from a visual event are presented. When the acceleration stage is over, the speed of perception becomes stabilised. We have shown recently that the initial acceleration of perception cannot be restricted to the phenomena that are related to motion processing. Similar acceleration with similar time epochs can be observed also if the replicas of the stimulus event are exposed with "zero-motion", i.e. if they are spatially invariant (Bachmann, Põder, 2001). However, the explanation offered here can survive motionlessness of the stimulus signals: for the attentional modulator there is no difference in general whether the stimulation replicas are spatially translated to adjacent positions in space or whether they involve "zero-translation", i.e., are overlapping. The present attentional account is reminiscent of the orienting reflex phenomenon (Sokolov, 1963) where the signals that have arrived earlier modulate processing of the signals that are input later; the nonspecific attentional effects follow the specific analysis performed perhaps implicitly before establishing explicit representation. At the level of neural implementation it has been shown that the pertentional retouch model (Bachmann, 1984, 1994, 1999) assuming that nonspecific thalamic modulation plays the role of attentional modulator, can well account for all of the phenomena described. The present account therefore follows earlier directions put forward by Fechner (1882). He suggested that what has to be developed is the so-called "inner psychophysics" where the explicit perceptual phenomena receive their explanations as grounded on the knowledge of how neuronal mechanisms of perception and attention work in the specific conditions that lead to one or another experienced phenomenon.

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