Spatial and non-spatial aspects of visual attention: interactive cognitive mechanisms and neural underpinnings

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Visual attention is broadly defined as the ability to rapidly detect and respond to stimuli within the surrounding environment, and to effectively select between relevant and irrelevant visual information. As a complex cognitive function, attention entails multiple components or dimensions, sub-served by widely distributed but highly specialised fronto-parietal neural networks, and including both spatial and non-spatial attentional mechanisms. Spatial attention (defined as the ability to direct attention to a particular location in space) has been extensively investigated in both healthy controls and neuropsychological patients. Particular emphasis has been placed on spatial biases in visual attention, manifested in the healthy population as so-called pseudoneglect (i.e., a leftward attentional bias when performing cognitive tasks; e.g., Bowers & Heilman, 1980; Jewell & McCourt, 2000; McCourt & Jewell, 1999; Sosa, Teder-Salejarvi, & McCourt, 2010) or in neuropsychological patients as so-called unilateral neglect (i.e., the distinctive rightward attentional bias resulting from right-hemispheric brain damage; e.g., Driver & Mattingley, 1998; Halligan, Fink, Marshall, & Vallar, 2003; Heilman & Valenstein, 1979; Vallar, 1998). The spatial allocation of visual attention can be defined within different reference frames (for a review see Farah, Brunn, Wong, Wallace, & Carpenter, 1990; Humphreys, Gillebert, Chechlacz, & Riddoch, 2013), with spatial locations defined with respect to the viewer (viewer-centred), based on external references (environment-centred), or according to locations within individual objects (object-centred). However, a purely spatial account of visual attention fails to explain the complexity of the underlying cognitive mechanisms, and over the years a substantial amount of evidence has been compiled about the non-spatial aspects of visual attention, which have been shown to significantly influence the spatial aspects. For instance, changes in alertness, attentional load, or attentional processing resources are known to influence the spatial deployment of visual attention and its biases. The nature of the interplay between spatial and non-spatial processes in visual attention, the mechanisms guiding them, and their common versus dissociate neural underpinnings are a matter of ongoing debate and of intensive research. Accordingly, many newer models of the neural underpinnings of attentional control in the human brain stress the importance of the interactions between spatial and non-spatial facets of visual attention.

Therefore, with this special issue, we aimed to provide an updated overview of some of the main trends in visual research concerned with how different spatial and non-spatial attentional functions, and their neural underpinnings, interact and contribute to human attentional abilities. The studies compiled here provide evidence based on a variety of research approaches and techniques, including, but not limited to, cognitive assessment, eye-tracking, and brain imaging in healthy controls and neuropsychological patients. In the present editorial, we highlight some of the themes that emerge through the submitted works (2 reviews and 17 original papers), which we divided into four parts: 1) neural underpinnings of spatial and non-spatial visual attention aspects; 2) visual attention in different spatial and temporal reference frames; 3) visual perception, eye movements, and the analysis of non-spatial factors in the deployment of visual attention; and 4) non-spatial factors in the modulation of visuospatial attention: evidence from studies in right- and left-hemispheric stroke patients.

Neural Underpinnings of Spatial and Non-Spatial Visual Attention Aspects

Visual attention operates via fronto-parietal networks, divided into dorsal and ventral attention systems, with distinct functional roles (Corbetta & Shulman, 2002; Mesulam, 1990). The dorsal network, including several core cortical regions, such as the intraparietal sulcus and the frontal eye field, controls the orientation of attention in space and top-down selection. The ventral network is involved in target detection and reorientation of attention towards salient, unexpected stimuli, and its core regions include the temporoparietal junction (TPJ), the anterior insula, and the ventral frontal cortex (Corbetta & Shulman, 2002). While it has been suggested that the dorsal network is organized bilaterally, it is thought – based on evidence from functional neuroimaging studies and neuropsychological patients – that the ventral attention network is strongly lateralized towards the right hemisphere (Corbetta & Shulman, 2002, 2011). The interplay between dorsal and ventral systems is critical for attentional control, requiring the integration of bottom-up sensory information with top-down signals, guided by current behavioural goals and task demands (Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002). Several long association fronto-parietal pathways, including three separate branches of the superior longitudinal fasciculus (SLF I-III) and the inferior fronto-occipital fasciculus (IFOF), provide essential structural connectivity within attention networks, affording functional interactions within and between dorsal and ventral attentional systems, as well as spatial and non-spatial facets of visual attention (e.g., Bartolomeo, Thiebaut de Schotten, & Doricchi, 2007; Chechlacz, Gillebert, Vangkilde, Petersen, & Humphreys, 2015; Doricchi, Thiebaut de Schotten, Tomaiuolo, & Bartolomeo, 2008; Schmahmann, et al., 2007; Thiebaut de Schotten, et al., 2011). The importance of such interactions has been confirmed by several studies examining functional connectivity, based on a variety of different neuroimaging approaches (e.g., Fox, Corbetta, Snyder, Vincent, & Raichle, 2006; He, et al., 2007; Leitao, Thielscher, Tunnerhoff, & Noppeney, 2015).

In this special issue, Fellrath et al. (2016) provide compelling evidence for interactions between spatial and non-spatial attentional mechanisms in the dorsal attentional system. Specifically, using resting-state electroencephalography (EEG) analysis, the authors demonstrate that the functional connectivity within the dorsal network predicts impaired goal-directed processing in patients with spatial attention deficits (Fellrath, Mottaz, Schnider, Guggisberg, & Ptak, 2016).

It is widely accepted that limited processing resources are allocated on the basis of dynamically changing "attentional priority maps", providing topographical representations of the visual scene, in which each object/location has an assigned, specific "weight", based on perceptual saliency and behavioural relevance (e.g., Bays, Singh-Curry, Gorgoraptis, Driver, & Husain, 2010; Bisley & Goldberg, 2010; Bundesen, 1990; Ptak, 2012; A. Treisman, 1998). Among different cortical areas within the dorsal and ventral networks involved in attentional control, the posterior parietal cortex (encompassing the TPJ, and the inferior and superior parietal lobules) has been indicated as a key region in encoding spatial priority maps (e.g., Husain & Nachev, 2007; Ptak, 2012). The review by Shomstein and Gottlieb (2016), included in this special issue, presents and critically evaluates experimental findings from human neuroimaging and monkey neurophysiological studies, supporting the existence of several interactions between spatial and non-spatial attentional processing, supported by the posterior parietal cortex. Shomstein and Gottlieb (2016) elegantly put forward an integrative model of the function of the parietal cortex in attentional selection, arguing that accumulated evidence indicates that priority maps reflect both spatial and non-spatial priorities, which ultimately act on sensory information in a spatial way. A second review by Clarke and Crottaz-Herbette (2016), also included here, discusses the neural mechanisms subtending prism adaptation (PA) in both neglect patients and healthy controls, focusing on the interactions between spatial and non-spatial attentional functions, and with respect to the PA-induced modulation of the interplay between dorsal and ventral networks. As numerous prior reports demonstrate, rightward PA triggers changes in the visual field representations from the right to the left inferior parietal lobule, resulting in a Shift of Hemispheric Dominance within the Ventral Attentional System (SHD-VAS model). Consequently, based on the reviewed evidence, Clarke and Crottaz-Herbette (2016) conclude that, as a consequence of this change, in neglect patients the visual input might be redirected to the dorsal network. This, in turn, might re-install the balance between left- and the right-hemispheric network components. However, as the authors note, while the SHD-VAS model provides a plausible explanation for the effects of rightward PA on attentional biases in patients with left neglect, it is still unclear whether this model can be generalized to leftward PA.

Visual Attention in Different Spatial and Temporal Reference Frames

One of the critical issues for understanding cognitive processes underlying visual attention is attentional selection. The environment relentlessly delivers a large amount of visual information, which needs to be prioritized on the basis of the current behavioural goals. This prioritization process can predict the locus of attention, i.e., the visual stimuli with the assigned greatest behavioural priority are the best candidates for attentional selection, and determine the spatial allocation of attention (Koch & Ullman, 1985). The allocation of attention can be defined in different spatial reference frames (for a review see, e.g., Farah, et al., 1990; Humphreys, et al., 2013), with spatial locations defined with respect to the viewer (viewer-centred), based on external references (environment-centred), or according to spatial locations within individual objects (object-centred), representing the space in relation to the planned behavioural actions towards visual stimuli. Furthermore, the successful selection of relevant objects, i.e., the successful interpretation of complex visual scenes, requires mechanisms enabling the effective structuring and organization of the incoming visual inputs. One of the mechanisms allowing the integration of visual objects within visual scenes, as well as of individual elements of complex objects into coherent wholes, is grouping (Koffka, 1935; Wertheimer 1923). While it is clear that object integration relies both on grouping processes and on selective attention, the precise nature of the relationship between attention and grouping is still the matter of ongoing research. In particular, it has been questioned to what extent attention is required for integrating information about features and object fragments into coherent wholes (see, e.g., Gilchrist, Humphreys, & Riddoch, 1996; A. M. Treisman & Gelade, 1980). In order to address some of these issues, Gögler and colleagues examined the role of selective attention in object integration processes in patients with visual extinction, resulting in clear spatial attention biases, using a visual search paradigm with Kanizsa figures (Gögler, Finke, Keller, Muller, & Conci, 2016). The contrasting findings in healthy participants and in patients with unilateral extinction indicate that attentional competition clearly limits integration processes. Thus, the study by Gögler et al. (2016) critically adds to the body of evidence suggesting that attentional resources are necessary for integrating parts of visual objects into coherent wholes.

While research on attentional selection and spatial priority maps predominantly focuses on the role of the parietal lobes, the report by Smith and colleagues examined the role of the Lateral Occipital Cortex (LOC) in object-based attentional facilitation and inhibition (Smith, Ball, Swalwell, & Schenk, 2016). Based on the examination of a patient with visual form agnosia resulting from bilateral occipital lesions, the authors provide evidence that the LOC is involved in object-based attentional facilitation, whereas object-based attentional inhibition does not depend on the integrity of this cortical area. The findings are compatible with prior neuropsychological evidence, suggesting a key role of the parietal cortex in mediating object-based inhibition, and proposing functional dissociations between object-based attentional facilitation and object-based attentional inhibition (e.g., Vivas, Humphreys, & Fuentes, 2008).

Another critical issue for understanding human attentional abilities is related to the temporal aspects of visual perception and attention. The temporal dynamics of attention can be described with respect to two different timescales (i.e., two different temporal frames): a very short timescale, measured in intervals of milliseconds, and a longer timescale, measured in intervals of minutes or even hours. These two timescales are labelled as so-called phasic alertness and tonic alertness/sustained attention, respectively (e.g., Coull, Nobre, & Frith, 2001; Posner, 2008; Sturm, et al., 1999; Sturm & Willmes, 2001). A novel measure for evaluating sustained attention is presented in this special issue by Shalev, Demeyere, and the late Glyn W. Humphreys. Shalev et al. (2016) argue that their task, a variation of the frequently used Continuous Performance Task (CPT; Conners & Staff, 2000), provides a reliable and accurate measure of sustained attention, which is free from the issues resulting from the reliance on estimates based purely on reaction times. Moreover, Shalev et al. (2016) found significant correlations between sustained attention, as measured by their task, and self-reported distractibility, in both elderly participants and in chronic stroke patients. The findings are discussed in relation to the applicability of this novel task for the evaluation of attentional problems in clinical populations.

Visual Perception, Eye Movements, and the Analysis of Non-Spatial Factors in the Deployment of Visual Attention

A central issue in visual attention research concerns its relationship with visual perception, and the reciprocal modulation of these two processes. The Theory of Visual Attention (TVA; (Bundesen, 1990) provides a computational framework for understanding visual attention in terms of 'biased competition', where visual categorizations of objects compete for limited processing capacity. The typical application of a TVA model to a free recall task allows the estimation of several attentional functions, including visual short-term memory capacity (visual apprehension span), processing speed, perceptual threshold of visual detection, spatial distribution of attention, and distractibility. Here, Staugaard, Petersen, & Vangkilde (2016) investigated the effects of stimulus eccentricity on distinct components of visual attention, applying the TVA framework, with and without stimulus magnification. The results suggest that an increasing eccentricity triggers a general decrease in attentional capacity, irrespective of magnification. Interestingly, the authors propose that the patterns of results cannot be exclusively explained by mechanisms related to cortical magnification or attention, but are likely to results from an interaction of the two. Moreover, the authors discuss the implications of applying specific experimental paradigms and stimulus material. The TVA model was also applied by Petersen, et al. (2016), in order to examine the link between visual attentional capacity (in terms of both visual apprehension span and visual processing speed) and alexia, resulting from unilateral left- or right-hemispheric strokes in the territory of the posterior cerebral artery. The findings show that the unilateral lesions could result in either unilateral or bilateral impairments in visual apprehension span, despite the preservation of processing speed. Moreover, an impaired visual apprehension span, in particular in the right visual field, seemed to affect reading impairments irrespectively of the side of the lesion. The findings are further discussed in the context of the role of visual attention in theoretical models of single word reading.

Another central question concerns the interplay between early and late, higher-order cortical visual areas, and the influence of such interactions on visual attention. The classical view holds that the activity of early, retinotopic cortical regions of the ventral visual cortex is mainly modulated by the spatial position of the stimuli, whereas the activity of later, higher-order regions is manly modulated by information concerning the category of stimuli, abstracted from their spatial location. However, recent evidence suggests a less exclusive and more interactive organization of those areas. In this special issue, Uyar and colleagues used functional magnetic resonance imaging (fMRI) in order to provide additional support for this interactive model (Uyar, Shomstein, Greenberg, & Behrmann, 2016). They elegantly show that, on the one hand, the effects on cortical activity driven by spatial position are observable also in later, higher order regions of the ventral visual cortex and, on the other hand, the effects driven by category of stimuli are also observable in early, retinotopic areas. The patterns of functional connectivity demonstrated by the authors within these areas also suggest a graded and bi-directionally connected system. Uyar et al. (2016) thus propose that the influence of the spatiotopic attentional modulation of complex representations may go beyond early retinotopic regions. Moreover, the connectivity within early and later visual areas may support the propagation throughout the visual system of signals influencing attentional control.

Visual attention has been often studied through systematic analysis of eye movements. Since the cortical representations of eye movements and spatial attention strongly overlap (e.g., Corbetta, et al., 1998; Nobre, Gitelman, Dias, & Mesulam, 2000), and attentional allocation and gaze have been shown to commonly move together in space when participants are free to move their eyes (e.g., Hoffman & Subramaniam, 1995; Shepherd, Findlay, & Hockey, 1986), eye movements are frequently employed as an indicator of the deployment of visual attention in space. Two papers included in this special issue analysed eye movements in order to assess the effects of a manipulation of non-spatial attentional aspects (i.e., fatigue or decreasing arousal) on the spatial deployment of visual attention. Paladini, et al. (2016) manipulated the level of fatigue in healthy individuals by means of increasing time-on-task, and measured spatial attentional deployment by means of a saccadic paradigm, in which horizontal left- and right-sided saccades had to be produced. The authors showed that, with increasing time-on-task and fatigue, the attentional deployment was affected asymmetrically, in that attentional disengagement costs became significantly lower for rightward than for leftward saccades. Moreover, a general (i.e., non-lateralized) decrease of saccadic velocity was also observed with increasing time on task, which is commonly thought to reflect an increased level of fatigue. These results seem to support the notion that spatial and non-spatial (in this case fatigue) attentional aspect interact, whereby non-spatial attentional aspects can trigger asymmetries in the spatial deployment of attention (in this case attentional disengagement, depending on the direction of the subsequent attentional shift). Fimm and Blankenheim (2016) applied a similar saccadic paradigm to measure spatial attentional deployment, and manipulated non-spatial attentional aspects by means of sleep deprivation in healthy individuals, i.e., the participants were repeatedly tested every four hours over a twenty-four-hour period, while being sleep deprived. Low arousal due to sleep deprivation triggered a general (i.e., non-lateralized) decrease in saccadic velocity, which was consistent with the results of the other, above-mentioned study. Interestingly, the authors also found significant effects of decreasing arousal on attentional disengagement. However, these effects were not direction-specific, i.e., did not differentially affect attentional disengagement depending on the direction of the subsequent attentional shift. The authors interpret the lack of lateralized effects as a potential indication for a non-overlapping representation of overt and covert attentional systems in the brain, and for a differential sensitivity of these systems to changes in the arousal level. A direct comparison of the paradigms applied by Paladini et al. (2016) and Fimm et al. (2016) reveals at least two central differences: i) the type of manipulation of non-attentional aspects, i.e., increasing fatigue due to increasing time on task vs. decreasing arousal due to sleep deprivation; and, ii) the amount of trials administered during a testing session (with lateralized effects on attentional disengagement seeming to appear only after a conspicuous amount of trials). Overall, the results seem thus to support the idea that eye movement analysis can reveal interactions between non-spatial attentional aspects and spatial ones. However, the intriguing pattern of changes in the results, triggered by small differences in experimental manipulations, suggests that these interactions are far from being fully understood, calling for further research in this direction. Another important question concerns the exact temporal dynamics guiding, on the one hand, attentional shifts and, on the other hand, gaze shifts in form of saccades. According to the premotor theory of attention (e.g., Rizzolatti, Riggio, Dascola, & Umilta, 1987), covert shifts (i.e., without eye movements) of attention correspond to the planning phase of saccades, i.e., the programming of their direction and amplitude. Here, a paper by Huber-Huber et al. (2016) proposes a novel method for investigating covert shifts of attention prior to and during saccades, by means of temporally aligned event-related potentials (ERPs). The authors show laterality effects (i.e., contra- vs. ipsilateral differences) in ERPs at posterior electrode sites, which are suggestive of attentional shifts taking place before saccade onset, in keeping with the premotor theory of attention (Huber-Huber, Ditye, Marchante Fernandez, & Ansorge, 2016). Moreover, by contrasting the results of trials with one or two targets, ERPs measured before saccadic execution indicated that covert attention can be allocated in parallel to more than one location simultaneously. The results are not only relevant for understanding the relationship and temporal dynamics between covert and overt attentional shifts (i.e., with and without eye movements), but also for the technical aspects linked to the application of ERPs in comparison to other psychophysical approaches.

Finally, Kalanthroff and colleagues assessed the influence of a rarely studied non-spatial factor, namely uncertainty, on the behavioural performance in a visual search, a task frequently used to measure the spatial deployment of visual attention (Kalanthroff, Linkovski, Henik, Wheaton, & Anholt, 2016). The authors examined young healthy controls to probe the relationship between inhibition and behavioural responses to uncertainty in a combined visual-search and stop-signal task**.** Specifically, in their experimental design, Kalanthroff et al. (2016) manipulated inhibition through varied proportions of stop-signal trials (high or low density of stop signals), and showed that participants are slower under the low density condition than under the high density condition on target-absent trials, but not on target-present trials, during the visual search task. These findings indicate that inhibitory control may causally affect behavioural responses to uncertainty, potentially having strong clinical implications relevant to anxiety and obsessive-compulsive disorder**.** Overall, the results point to the effects of the manipulated non-spatial factors (uncertainty and inhibition) on the performance in spatial visual attention and target identification tasks.

Non-spatial Factors in the Modulation of Visuospatial Attention: Evidence from Studies in Right- and Left-Hemispheric Stroke Patients

The cognitive mechanisms underlying spatial attention have been commonly studied in patients with unilateral neglect, who distinctively lack awareness of the side of space contralateral to brain damage (Heilman & Valenstein, 1979). Typically, neglect patients fail to direct their attention to the left side of space after right-hemispheric brain damage. However, spatial biases can also arise following left-hemispheric damage. Furthermore, neglect is a very heterogeneous syndrome, and the observed striking spatial deficits are differentially modulated by non-spatial factors, such as alertness, sustained attention, task demands, and attentional load (Corbetta & Shulman, 2011).

Two studies included in this special issue explored the link between attentional load and the spatial biases observed in patients with unilateral attentional deficits (Blini, et al., 2016; Ricci, et al., 2016). In their paper, Blini and colleagues (Blini et al., 2016) examined the effects of cognitive load on the occurrence of lateralized spatial attention deficits in left-hemispheric stroke (LHS) patients. The authors elegantly show that the deficits are only manifested under additional cognitive load conditions (concurrent secondary task/multitasking condition). Based on the comparison with both age-matched elderly controls and with patients with mild cognitive impairment, the authors attribute the observed pathological spatial bias in a spatial monitoring task (both in the visual and the auditory modality) – arising in LHS patients only under the multitasking condition – to the specific consequences of unilateral brain damage, and not the global reduction of cognitive resources. Blini et al. (2016) thus conclude that the observed effects of multitasking are best explained by means of the interactions between spatial and non-spatial components of attention. In another report presented here, Ricci et al. (2016) examine whether a cognitively demanding, non-spatial task would affect the severity of spatial neglect symptoms observed in patients with right-hemispheric lesions. The authors clearly demonstrate that non-spatial cognitive load triggers a worsening of the spatial exploration bias in neglect, as measured by the performance in a cancellation task. The authors suggest that the observed exacerbation of neglect symptoms (spatial deficits), triggered by a demanding non-spatial task, could be attributed to an additional deficit in sustained attention.

Another important domain of research concerns the interactions between visuospatial attention and motion, an omnipresent visual feature in everyday life. Motion with specific and coherent directional features, particularly on the horizontal plane, has been shown to influence the spatial deployment of visual attention in patients with attention deficits, such as unilateral neglect after right-hemispheric stroke (e.g., the positive effects of smooth pursuit training, with slow coherent motion towards the contralesional side, in neglect patients; Kerkhoff, et al., 2014). However, the effects of other types of motion, such as rotational or naturalistic motion, are far less known. Three papers included in this special issue investigated different aspects of the interactions between directionally non-specific motion and spatial deployment of visual attention (Cazzoli, et al., 2016; Reinhart, et al., 2016; Schaadt, et al., 2016). Schaadt et al. (2016) assessed the effects of rotational random dot motion on the visual judgment of line orientation, an important visuo-perceptual ability. In a judgment task, the authors presented oblique lines to 20 patients with right-hemispheric lesions (10 with and 10 without difficulties in the line orientation judgment test; almost all impaired patients also presenting neglect signs to different extents) and to 10 healthy controls, either with a static background or with a circular random dot motion background (clockwise or counter-clockwise). Impaired right-hemispheric patients showed a counter-clockwise tilt in their judgment (correlated with neglect severity), which remitted with clockwise motion and slightly exacerbated with counter-clockwise motion. The results were similar in the groups of unimpaired patients and of healthy controls, i.e., had the same direction, but with a markedly smaller amplitude. In a companion paper, Reinhart et al. (2016) assessed the effects of rotational, coherent dot motion on the judgment of the subjective visual vertical in 20 patients with right-hemispheric lesions (10 with and 10 without difficulties in the subjective visual vertical judgment task; almost all impaired patients also presenting neglect signs to different extents) and to 10 healthy controls. The trials of the task were presented either on a static background, or accompanied by slow clockwise or counter-clockwise rotational coherent dot motion. In the static condition, impaired patients showed a counter-clockwise tilt in their subjective visual verticality judgment, which normalized with clockwise rotational coherent dot motion and slightly exacerbated with counter-clockwise motion. Again, the result patterns showed the same direction, but were quantitatively much smaller, in patients unimpaired in the subjective visual verticality judgment task and in healthy controls. Taken together, the findings by Schaadt et al. (2016) and by Reinhart et al. (2016) thus show that slow, rotational dot motion can have a significant and positive influence on impairments in line orientation judgment and subjective visual vertical judgment in patients with right-hemispheric stroke. The findings are interpreted as the result of a possible modulation of higher-order spatial representations involved in orientation and verticality judgment. Moreover, attentional mechanisms are also considered, interacting with reduced perceptual constancy in patients with impaired orientation or subjective visual vertical judgment, and giving rise to greater variability in behavioural performance and greater modifiability by external cues. Finally, the authors hypothesize that spared areas of distributed cortical networks, with a central role of the parieto-temporal cortex, may subtend the positive effects of rotating visual motion. These findings are not only relevant for the understanding of the basic mechanisms subtending the influence of motion on orientation and verticality judgement, but may also have implications for recovery and treatment of the patients. Another study, presented here by Cazzoli et al. (2016), assessed the influence of a different type of directionally non-specific motion, i.e., naturalistic motion, without specific spatial directional features, as implemented in a virtual traffic scene. The authors measured visual exploration under static (no motion) and dynamic (directionally non-specific motion) conditions, in a group of healthy controls and in three groups of patients with right-hemispheric stroke in the subacute/chronic stage, i.e.: patients with unilateral neglect and visual field defects (VFD), patients with VFD but no neglect, and patients without any VFD or neglect. Naturalistic, directionally non-specific motion triggered differential effects on the visual exploration patterns of the different groups of patients. Under dynamic conditions, patients with neglect and VFD explored less the contralesional space, whereas patients with VFD but no neglect explored more the contralesional space. In contrast, no significant changes were observed under dynamic conditions in the healthy controls or in the right-hemispheric patients without any VFD or neglect. The results thus suggest that naturalistic, directionally non-specific motion can influence the spatial deployment of visual attention in right-hemispheric stroke patients. The findings are discussed in the context of the higher demands potentially imposed by the dynamic condition, and the differential possibilities to compensate for this higher demands in right-hemispheric stroke patients with VFD, with or without additional unilateral neglect.

Finally, Li and colleagues examined the link between motivation and attentional processes in neglect patients (Li, et al., 2016)**.** This elegant study in right-hemispheric patients, with either recovered or persistent neglect, examined the possible effects of monetary reward (as a motivational factor) on the pathologically prolonged attentional blink associated with the neglect syndrome. The authors showed that a reward has indeed a modulatory effect on the attentional blink, but only in patients with recovered neglect, and not in patients with persistent neglect symptoms. This finding is interpreted by the authors with regards to the separate effects of reward and performance feedback on non-lateralized attentional deficits, and to a potential role of motivational responsiveness in neglect recovery.

Conclusions

The papers collected in this special issue show that the interactions between spatial and non-spatial aspects of attention are numerous and highly complex. The presented evidence demonstrates that these interactions span from the level of the neural underpinnings to the behavioural outcomes, as examined in both healthy controls and in patients with acquired brain damage, and as assessed with diverse techniques, ranging from cognitive assessment to functional imaging, eye-tracking, event-related potentials, EEG connectivity, and lesion analysis. Furthermore, the examined non-spatial factors interacting with the deployment of spatial attention are numerous, and range from perceptual to motivational factors. Overall, the papers included here present several novel and fascinating findings concerned with the dynamic functional interplay between different spatial and non-spatial attentional aspects, their neural underpinnings, and their contribution to human attentional capabilities. But beyond that, these papers also generate further important questions and issues, which will help to stimulate new research efforts in this growing and interactive field of research.

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