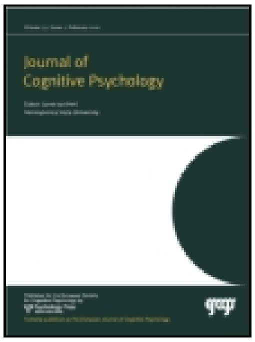

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Media multitasking predicts unitary versus splitting visual focal attention

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Research evidence now suggests that the deployment of multiple attentional foci in noncontiguous locations (i.e., splitting visual focal attention) is possible under some circumstances. However, the exact circumstances under which focal attention might 'split' have not been well understood. Here, we examined the possibility that ecological differences arising from our increasingly media-saturated environment result in individual differences in the capacity to demonstrate splitting focal attention. The Media Multitasking Index (MMI) was used to assess the extent to which participants engaged in media multitasking—the consumption of more than one stream of media content at the same time. Capacity to split attention was assessed with a paradigm previously employed by McCormick, Klein, and Johnston. The present data suggest a significant relationship between the behavioural preference for consuming multiple media forms simultaneously and the capacity to employ a split mode of attention. Specifically, High-MMI participants (who tend to consume multiple visual media forms simultaneously) adopted a splitting mode of visual attention, whereas Low-MMI participants (who tend to consume fewer visual media forms simultaneously) adopted a unitary mode of attention. These data advanced our understanding of the circumstances under which visual focal attention might split. Implications and future directions are discussed.

Keywords: Individual differences; Multitasking; Splitting visual attention.

For decades now, vision scientists and researchers have tried to understand what attention is, and how it works. Two well-known models have been used to describe the deployment and focus of visuospatial attention. Posner (1980) described attention as a 'spotlight'—a beam of fixed diameter where the processing of information within its range is enhanced. In light of evidence that the spatial extent of attentional focus was more variable than Posner (1980) believed, Eriksen and St. James (1986) analogised attention to a 'zoom lens'. In their interpretation, the region of attentional focus could be volitionally varied in size according to task demands.

A common position in both models is that there can only be one unified region of attentional focus at any point in time. In other words, attention cannot be 'split' and deployed to noncontiguous locations simultaneously. In order to cope with scenes composed of multiple visual stimuli, Posner (1980) and Eriksen and St. James (1986) suggested that the attentional focus would need to serially shift to different spatial locations (see also Tsal, 1983). In particular, the zoom lens model allows for spatial expansion of the attentional focus to encompass multiple stimuli, with parallel processing of stimuli taking place (see Pan & Eriksen, 1993 for a discussion).

Empirical support for the unitary nature of attentional focus is available in two forms. The first is the observation that cuing benefits cannot be reaped at multiple locations simultaneously. For instance, Eriksen and Yeh (1985) presented

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participants with an array of eight letters in a circular pattern, and tasked them to identify the presence of one of two potential target letters. Targets could appear at four positions: 3, 6, 9 or 12 o'clock. In the divided attention condition, a single cue indicating a pair of possible target locations was presented prior to target appearance. This was achieved by instructing participants to attend to both the primary position at which the cue appears, as well as the secondary position diametrically opposite it (e.g., 6 and 12 o'clock). Eriksen and Yeh (1985) reasoned that if focal attention could be divided, reaction times (RTs) at both the primary and secondary positions would reflect cuing benefits. Results showed that cuing benefits obtained only at the primary position, suggesting that participants were sequentially searching the primary and secondary positions. This was taken as supportive evidence for the unitary focal attention account, as well as evidence that focal attention shifts to process stimuli that are sufficiently far apart from each other.

The second form of evidence for unitary attention has its basis in one of the key predictions of the zoom lens model: when presented with stimuli in two noncontiguous locations, the attentional focus should expand to encompass both locations. This suggests that distractors appearing between the locations should fall within the region of attentional focus. Participants will thus be unable to ignore these distractors. Such an observation was made by Pan and Eriksen (1993). Participants were presented with paired combinations of the letters S and H, at varying distances apart from each other in what were essentially noncontiguous locations. Their task was to identify if the letter pair presented was the 'same' (i.e., S-S, H-H) or 'different' (i.e., S-H). On each 'same' trial, distractors were presented between the letter pair that could be incompatible (e.g., H for S-S pair) or compatible with the letter pair. Results revealed that trials with incompatible distractors had significantly slower RTs than trials with compatible distractors, which suggests that participants were unable to selectively ignore the irrelevant region between each letter pair. Here again, this was interpreted as support for the unitary attention account.

A notable number of other studies have provided converging evidence supporting the general principal that focal attention cannot be split (e.g., Heinze et al., 1994; Jonides, 1983; McCormick & Klein, 1990; Posner, Synder, & Davidson, 1980). However, beginning in the late 80s and early 90s, dissenting voices began to emerge in the attention research community. These researchers proposed the contrasting position that focal attention could be divided over noncontiguous locations in the visual field (Castiello & Umiltà, 1992; Driver & Baylis, 1989; LaBerge & Brown, 1989). In the subsequent 20 years, we witnessed a growing body of evidence in support of this position.

THE CASE FOR SPLIT FOCAL ATTENTION

The contrast between unitary and split attention relates to how flexibly attention can be deployed. The key implication of unitary attention—that attention can only be deployed in a single contiguous region at any particular point in time—suggests a rather simplistic (and inflexible) visual system. This simplicity is also partly the reason why unitary attention models are theoretically attractive (Cave, Bush, & Taylor, 2010).

However, it is important to bear in mind that in contrast with controlled experimental settings, the real world requires the constant processing of rather complex scenes. Converging evidence suggests that people can rapidly extract the general meaning of novel complex scenes with ease, often needing only a 'single glance' (Loschky et al., 2007, p. 1431). It has also been shown that scene information can be extracted even when attention is focused on other parts of the visual field (Li, VanRullen, Koch, & Perona, 2002). This ability to quickly and efficiently extract information about multiple visual stimuli in different locations suggests that humans possess a visual system that is far more complex and flexible than we would have imagined.

Furthermore, from a purely theoretical perspective, attention need not be unitary for the spotlight and zoom lens models to work (Castiello & Umiltà, 1992). Other key features of these models are compatible with the idea of split attention as well. For instance, the ability to deploy attention in noncontiguous locations is not mutually exclusive with the ability to shift the region of attentional focus or vary its size. It would appear that the notion of unitary attention is based on empirical, rather than theoretical, grounds.

Consequently, many researchers have attempted empirical challenges in the form of evidence for split attention, and the past 20 years had witnessed such evidence from a diverse range of studies (for a full review, see Jans, Peters, & De Weerd, 2010; cf. Cave et al., 2010). To highlight this diversity within the limits of this paper, recent results from one psychophysical, electrophysiological and neuroscientific study will be chosen and discussed in some detail.

Psychophysical evidence

In Experiment 1a of Awh and Pashler (2000), participants were presented with a 5 × 5 array of characters and tasked to report the identity of any digits. Prior to the onset of the array, two cues at noncontiguous locations were shown. Both cues were valid on 80% of trials, whereas on remaining trials only one target would appear between the cued locations. Results revealed a strong accuracy advantage for validly cued targets (73%) over targets that appeared between the cued locations (32%). This is contrary to the zoom lens interpretation of attention, which would propose a single region of attentional focus encompassing both cued locations and the irrelevant location in between. Identification accuracy should thus be similar for targets appearing in all locations within this region, which was evidently not the case. Awh and Pashler's results suggest that participants were able to selectively attend to the noncontiguous cued locations, which constitutes evidence of split attention.

Electrophysiological evidence

Electrophysiological evidence for split attention was found by Müller, Malinowski, Gruber, and Hillyard (2003), who utilised a measure known as the steady-state visual evoked potential (SSVEP). The SSVEP (Regan, 1977) is an electrophysiological response observed in the visual cortex when the retina is excited by stimuli being rapidly presented, or flickering, at a frequency of 3.5–75 Hz. This response takes the form of a sinusoidal wave that shares a frequency with the stimulus that triggers it. Prior studies have also established that the SSVEP wave amplitude increases significantly when attention is focused on locations with flickering stimuli (Müller et al., 1998). Hence, by presenting stimuli flickering at unique frequencies at different locations, and observing the amplitudes of the SSVEP waves at corresponding frequencies, it is possible to determine which locations are being attended to.

In the experiment, participants were presented with white rectangles at four different locations along the horizontal median, each flashing at a unique frequency. The locations and frequencies were as follows: Position 1 (leftmost) 15.2 Hz, Position 2 (middle-left) 8.7 Hz, Position 3 (middle-right) 20.3 Hz and Position 4 (rightmost) 12.2 Hz. During each trial, a random sequence of five red symbols was presented at each position, and participants were instructed to attend to two of the four positions. The task was to determine if simultaneous presentation of a target symbol at these two positions was detected. The location pairs that participants attended to could either be adjacent (1 + 2, 3 + 4), or noncontiguous (1 + 3, 2 + 4).

To investigate split attention, SSVEP amplitudes for the adjacent and noncontiguous conditions were compared. It was noted that SSVEP amplitude for the intermediate locations in the noncontiguous conditions was significantly lower than when these locations were attended to in the adjacent conditions. For instance, the SSVEP amplitude at location 3 when participants attended to 2 + 4 was significantly lower than when attention was directed to 3 + 4. This suggests that attention was not being deployed to intermediate locations when participants were attending to noncontiguous locations. Here again, this aptly illustrates a case of split attention.

Neuroscientific evidence

McMains and Somers (2004) present functional magnetic resonance imaging (fMRI) evidence for split attention. Previous research has shown that neurons in the visual cortex are topographically organised in a two-dimensional representation of the portions of the visual field which they are receptive to (e.g., Wandell, Brewer, & Dougherty, 2005). fMRI procedures have been designed to obtain 'retinotopic maps' of this topographic organisation (Brefczynski & DeYoe, 1999). By observing the activity patterns on these maps, it is possible to infer which regions of the visual field a participant is attending to at a particular point in time.

McMains and Somers (2004) first obtained retinotopic maps of the visual cortex in each of their participants via preliminary fMRI scanning. During the experiment, five rapid serial visual presentation (RSVP) streams of letters and digits were presented to participants—one in each visual quadrant, and one in the centre. In the split attention condition, participants were instructed to attend to streams in opposing quadrants (e.g., upper left and lower right). These were essentially noncontiguous locations, divided by the central stream in between them. The experimental task was to detect when matching digits were presented in the two streams. Results revealed neural activity which restricted itself to the retinopic representations of the quadrants where the target streams were placed. This serves as evidence that participants were able to attend to the separate streams while selectively ignoring the central stream.

Thus far, we have described several traditional landmark studies (Eriksen & Yeh, 1985; Pan & Eriksen, 1993) that favoured a unitary attention account. We have also described recent developments in the literature (Awh & Pashler, 2000; McMains & Somers, 2004; Müller et al., 2003), which provided converging evidence in support of a splitting model of attention. In view of these opposing accounts, the logical question to ask and pursue concerns the conditions under which focal attention might (or might not) actually split.

WHEN (AND WHY) MIGHT FOCAL ATTENTION SPLIT?

The bodies of evidence in support of the unitary and split attention accounts are not necessarily mutually exclusive. It has been suggested that while attention can be split under some circumstances, unitary attention remains the default mode of attentional deployment (Cave & Bichot, 1999; Cave et al., 2010; Jans et al., 2010). The challenge is to determine what these circumstances are.

Past researchers have focused on paradigm differences between studies that support unitary and split attention. Kramer and Hahn (1995) addressed paradigms that involved the presentation of distractors between noncontiguous target locations (e.g. Heinze et al., 1994; Pan & Eriksen, 1993). It was proposed that evidence for split attention was not found because distractors in these studies were presented via sudden onset. The sudden appearance of stimuli has been known to capture attention involuntarily (Yantis, 1993; Yantis & Hillstrom, 1994). Hence, even if participants had been able to deploy attention to noncontiguous locations, they would not have been able to maintain this mode of attention in the face of sudden onset distractors.

Dubois, Hamker, and VanRullen (2009) addressed paradigms involving multiple cues at noncontiguous locations (e.g., Eriksen & Yeh, 1985; Posner et al., 1980). It was proposed that the critical factor was the stimulus onset asynchrony (SOA) between the cues and subsequent targets. Dubois et al. (2009) reported results suggesting that while attention could be split, the split mode of attention could only be maintained for a short duration (100–150 ms). Hence, if the SOAs between cues and targets were too long, attention would naturally regress to a default unitary mode.

In spite of these findings, the issue of when and why focal attention might split remains far from resolved. There have been contradictory reports where evidence for split attention has been found despite the use of sudden onset distractors (Bichot, Cave, & Pashler, 1999) and long SOAs between cues and targets (Castiello & Umiltà, 1992). It would appear that the reason beneath the conflicting results for and against split attention might be located elsewhere.

VIDEO GAMING AND MEDIA MULTITASKING

One intriguing possibility, which has yet to be investigated, is ecological differences. The twenty-first century has witnessed an exponential increase in the prevalence of digital devices in modern society, and a dramatic increase in media use (Rideout, Foehr, & Roberts, 2010). A set of literature had examined the impact of habitual action video game playing on visuospatial attention. Action video games, such as *Halo, Call of Duty* and *God of War*, often present game players with multiple stimuli and distractors that spread across the visual field, and which players must rapidly track and respond to in order to avoid adverse consequences. Expert video game players (VGPs) have been known to outperform nonvideo game players (NVGPs) in measures of simultaneous object tracking (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Trick, Jaspers-Fayer, & Sethi, 2005), spatial resolution of attention (Green & Bavelier, 2003), the amount and distribution of attentional resources (Green & Bavelier, 2006) and efficiency of a visual search over time (Castel, Pratt, & Drummond, 2005), among others (for a full review, see Hubert-Wallander, Green, & Bavelier, 2011). Furthermore, improvements in performance have been observed in NVGPs who are trained on action video games under experimental settings, suggesting that game playing has a causal role. Taken together, the evidence suggests that experience with the complex visuomotor tasks in action video games enhances various aspects of visuospatial attention.

Aside to video gaming, one behaviour of particular interest that is becoming increasingly common among youths and young adults is *media multitasking*—the consumption of more than one stream of content at the same time. The design of human cognition does not seem particularly suited for attending to and processing multiple streams of incoming information (see, e.g., Cherry, 1953; Wood & Cowan, 1995) or accomplishing multiple tasks concurrently (see, e.g., Dux, Ivanoff, Asplund, & Marois, 2006; Hein, Alink, Kleinschmidt, Müller, & He, 2007; Marois & Ivanoff, 2005). Yet, people are often dissatisfied with merely undertaking one task at a time, as Sanbonmatsu Strayer, Medeiros-Ward, and Watson (2013) very recently maintained. As such, people frequently multitask (i.e., engage in multiple tasks and aim to fulfil multiple goals concurrently), a phenomenon that continues to attract a considerable amount of research interest.

Researchers have investigated the effects of multitasking—particularly those of *media multitasking*—on memory (e.g., Foerde, Knowlton, & Poldrack, 2006), learning (e.g., Armstrong & Chung, 2000) and cognitive performance (e.g., Furnham & Bradley, 1997). More recently, Ophir, Nass, and Wagner (2009) examined the relationship between chronic media multitasking and cognitive control abilities, asking whether (and how) chronic heavy multitaskers process information differently than individuals who less frequently multitask. They addressed this question by comparing chronic heavy media multitaskers with those who infrequently multitask via a series of cognitive control studies. In order to identify individuals who are heavy, as opposed to light, media multitaskers, they developed a questionnaire-based MMI[1] to determine the mean number of media that an individual concurrently consumes whilst consuming media, and picked individuals who were heavy, or light, media multitaskers on this index, and accordingly deployed them to two separate groups. The researchers then examined these groups' performance on a number of tasks (e.g., the allocation of attention to environmental stimuli and their entry into working memory, the holding and manipulation of stimulus and task-set representations in working memory, and their control of responses towards stimuli and tasks), and discovered that heavy media multitaskers are more susceptible to interference from irrelevant environmental stimuli or irrelevant representations in memory than are light media multitaskers, suggesting significant individual differences in information processing approaches and measures of cognitive control (see also Lin, 2009).

Various research groups continued to investigate and reveal new interfaces between media multitasking and human cognition and behaviours. In order to determine the locus of the deficit that Ophir et al. (2009) reported (i.e., heavy media multitaskers are more disturbed by irrelevant information than are light media multitaskers), Cain and Mitroff (2011) isolated attentional processes by employing a singleton distractor task with low working-memory demands, and found that light media multitaskers used top-down information to enhance their performance whereas heavy media multitaskers did not, demonstrating attentional differences across groups and the crucial idea that heavy media multitaskers maintain a broader attentional scope than do light media multitaskers. Most recently, Sanbonmatsu et al. (2013) investigated the relationship between personality and individual differences in multitasking ability and found that heavy multitaskers have less executive control and have higher impulsivity; Minear, Brasher, McCurdy, Lewis, and Younggren (in press) discovered that heavy media multitaskers did report to be more impulsive, and also performed more poorly on measures of fluid intelligence than did light media multitaskers.

Investigations involving media multitasking have extended beyond the boundaries of cognitive psychology. Becker, Alzahabi, and Hopwood (2013), for instance, reported a unique association between media multitasking and symptoms associated with depression and social anxiety. In the light of these new and diverse interfaces between media multitasking and human functioning that are only beginning to be revealed, of particular interest to us is whether growing up in a media-rich

[1] Via the MMI, participants report the number of hours (per week) they use each of the following 12 primary forms of media: television, computer-based video, music, nonmusical audio, video or computer games, telephone and mobile phone, instant messaging, SMS (text messaging), email, web surfing, and other computer-based applications (such as word processing). Participants then indicate, for a particular primary media form, how often they use this media concurrently with the each of the other 11 media forms. The following ratings are used: ''Most of the time (= 1),'' ''Some of the time (= .67),'' ''A little of the time (= .33),'' or ''Never (= 0).'' All 11 responses are added to derive a measure of the amount of concurrent media used while using that primary form of media. Following which, this sum is multiplied by the number of hours using that form of media and divided by the total amount of time using all forms of primary media. This produces an index for that form of primary media; this index is calculated for each of the primary forms of media. The overall MMI score is the sum of these individual indexes. The MMI is taken to indicate the average degree of media multitasking that is taking place during a typical hour of media usage.

environment and consuming multiple visual media forms simultaneously, such that attention is being demanded by multiple locations at the same time, might encourage the development of the capacity to split attention. To the extent that media multitasking is indeed associated with early visual attentional processes (i.e., media multitasking predicts whether visual focal attention splits), these findings will be informative and well-positioned in the wider context of extant research on media multitasking and its particular relation to cognitive psychology.

THE PRESENT STUDY

To reiterate, the opposing accounts of split and unitary attention motivates the question of when and why visual focal attention might split. Here, we propose that by demanding the allocation of attention to multiple locations, today's media-saturated environment may encourage the development of the tendency to split visual attention. Specifically, we aim to discover if individual differences in the tendency to demonstrate split attention correlate with participants' media multitasking behaviour.

In our investigation, we adopted the MMI developed by Ophir et al. (2009), a measure of chronic media multitasking behaviour. Additionally, we employed a close replication of a paradigm used by McCormick, Klein, and Johnston (1998).

McCormick et al.'s (1998) goal was to locate evidence in support of unitary attention. To achieve this, they employed a variant of a 'probe paradigm' commonly used to determine the spatial extent of attention, in which target stimuli are occasionally presented at varying distances from a cued location (LaBerge, 1983). McCormick et al.s' (1998) main innovation was the introduction of a 'double cue' condition. In this condition, boxes 10° to the left and right of a central fixation point were simultaneously used to cue the subsequent onset of a target dot. The target could appear inside either box, or between a box and the central fixation. Participants were tasked with responding to the target once it appeared in their visual field. McCormick et al. (1998) predicted two different trends of results depending on the mode of attention employed (see Figure 1). In the event of a unitary mode, and in line with the predictions of the zoom lens model, attentional focus would expand to encompass both cued locations and the region between them. Thus, RTs for targets in

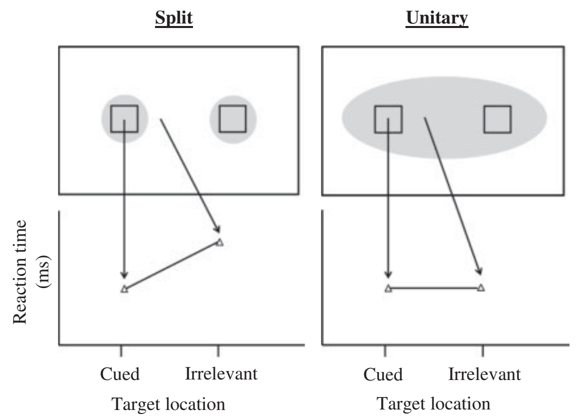

Figure 1. Predicted result trends depending on mode of attention employed in the double cue condition of McCormick, Klein, and Johnston (1998).

cued locations (i.e., in the boxes) would not differ from those in irrelevant locations (i.e., outside the boxes). Contrastingly, in the event of a split mode, only the cued locations would be attended to. Thus, RTs for targets in cued locations should show a cuing advantage over those in irrelevant locations. Results obtained were in line with the trend for unitary attention, and consistent with McCormick et al.s' (1998) hypothesis.

The main goal of replicating the paradigm in McCormick et al. (1998) is to establish that any difference in results stems from ecological, and not paradigm-specific, differences. Compared to the undergraduate population of year 1998, undergraduates today would have grown up in a far more media-saturated environment with simultaneous exposure to multiple rich streams of information being a common occurrence (Ophir et al., 2009; Pilotta, Schultz, Drenik, & Rist, 2004);our participants, unlike those in McCormick et al. (1998), should demonstrate split attention, on the basis that there has been a tremendous increase in terms of the amount of time that people spend multitasking with media (simultaneously accessing two or more forms of media), as recently reported by Rideout et al. (2010). Indeed, overall media use among America's youth alone had increased by 20% over the past one decade. Of particular interest to our present discussion is that the amount of time spent multitasking with media (simultaneously interacting with more than one form of media) had increased by over 119% over the same period. This dramatic shift in how people engage with media may be important to help us understand the relationship between media use (multitasking) and early visual processing.

Accordingly, we predict that splitting mode of attention occurs as a function of participants' media multitasking behaviour, as indicated by MMI scores:

(1) MMI should not influence subject performance in the single cue conditions. All participants should demonstrate faster RTs for targets that appear in cued locations, over those that appear in irrelevant locations.
(2) For the double cue condition, individuals who tend not to media multitask, as indicated by their Low MMI scores, should demonstrate unitary attention: RTs for targets at cued and irrelevant locations should be comparable.
(3) However, individuals who tend to media multitask, as indicated by their High MMI scores should demonstrate split attention: RTs for targets at cued locations should be significantly faster than for those at irrelevant locations.

METHOD

This research was conducted in two parts: a media use questionnaire and matrix, followed by a cognitive behavioural experiment.

Participants

Sixty-six introductory psychology students from the National University of Singapore participated to fulfil course requirements. All participants reported normal or corrected-to-normal vision.

Media use questionnaire and matrix

The questionnaire and matrix were close replications of those employed in Ophir et al. (2009), with one slight modification. Ophir et al. (2009) had included items about non-visual media forms, such as music, in their original study. Given that we are primarily interested in how deployment of visual attention works, all items unrelated to the present goal were removed. A decision was made to retain the 'Handphone' item, as technological advances have arguably transformed the handphone into a personal digital assistant used for many functions other than for phone calls.

The questionnaire addressed 10 different media forms: printed media, television, computer-based video (e.g., YouTube), video or computer games, noncall-related handphone use, online instant messaging, text messaging, email, web surfing and other computer applications (e.g., word processor). Participants were required to report the total number of hours spent per week on each media form. Furthermore, participants filled up a 9 × 10 media-multitasking matrix, indicating the degree to which, while engaged in one media form as a primary activity, they would concurrently use other forms of media as well (1 'Never', to 4 'Most of the time'). Text messaging was excluded as a primary media form in the matrix as its usage could not be accurately described as a function of time. However, it was still available as an option under concurrent activities.

Deriving MMI

The matrix responses were recoded as follows: 1 'Never' = 0; 2 = .33; 3 = .67; and 4 'Most of the time' = 1. Summing up responses for each primary media form gave a measure of the mean number of other media used concurrently with the primary activity. Finally, to account for the different amounts of time spent on each media form, MMI was derived by calculating a sum of this measure across all primary media forms, weighted by the percentage of time spent on each primary media form. This process can be summarised using the following formula:

$$\mathrm{MMI} = \sum_{i=1}^{10} \frac{m_i \times h_i}{h_{total}}$$

where m_i is the number of media typically used concurrently with the primary media form i, h_i is the number of hours per week reportedly spent using primary media form i and h_{total} is the total number of hours per week spent with all primary media forms.

Apparatus and setting

Each participant sat in front of a 24-inch colour monitor controlled by an Acer computer. Viewing distance between the eyes and monitor was set at approximately 50 cm. Responses were gathered on a standard computer keyboard.

Stimuli

The stimuli, design and procedure of our experiment were kept in accordance with Experiment 1 of McCormick et al. (1998), with slight modifications. McCormick et al. (1998) had varied the size of the cues used in the original study. The present study kept cue size constant. In addition, while participants completed fewer trials, the proportion of trials for each condition remained the same as McCormick et al.'s (1998) Experiment 1 (see Table 1).

The visual display comprised of a black background and centred white fixation cross (.4° by .4°). The cue used was an empty white-bordered square (1.1° by 1.1°), which appeared 10° to the immediate left of fixation, 10° to the immediate right of fixation or in both locations simultaneously. The imperative stimulus was a white dot (diameter .3°) positioned at one of four possible locations on the horizontal median (10° left, 5° left, 5° right or 10° right). Samples of all stimuli used are presented in Figure 2.

Task

The task was to detect and respond to the appearance of the imperative stimulus. Participants used the spacebar key of a standard keyboard to make responses.

Design

The experiment used a 3 × 4 fully within factorial design. The two independent variables were (1) type of cue: (a) single cue to the left, (b) single cue to the right and (c) double cue; and (2) location of target dot: (a) 10° left, (b) 5° left, (c) 5° right and (d) 10° right.

TABLE 1
Number of trials for each condition in the present experiment

	Target Location				
Cue type	*10° left*	*5° left*	*5° right*	*10° right*	*Catch*
Double Cue	60	10	10	60	20
Single Cue, Right	10	10	10	80	20
Single Cue, Left	80	10	10	10	20

Procedure

The sequence of events for each trial is illustrated in Figure 3. Each trial began with the presentation of the fixation cross for 800 ms. This was followed by a single or double-box cue. After a 515-ms interval, the target was presented and remained on screen along with the boxes until the participant responded. Participants were instructed to press the response key (spacebar) as soon as they detected the target, but to refrain from responding when the target did not appear (catch trials). After each response, there was a 1 sec interval where no stimuli appeared, before the next trial began.

Participants were informed that the box cues indicated the most likely location at which the target would appear, and to orient their attention to these locations. Participants were also informed that in the event of a double box cue, the target could appear at either location with equal probability. Participants were further instructed to attempt to divide their attention between the two boxes when presented with a double box cue.

Each participant took part in a single experiment session consisting of 15 practice and 420 experimental trials. Four rest periods were interspersed during this session. The total number of experimental trials for each cue-target combination is presented in Table 1.

RESULTS

Participant MMI scores ranged from .29 to 6.45, with an average of 3.15 and standard deviation of 1.37. There was no correlation between MMI score and the total number of hours spent on surveyed media forms each week, r (64) = .05, p = .67. In preparation for the subsequent main analyses, participants with above-average MMI scores were classified as High scorers, whereas those with below-average MMI scores were considered Low scorers. Two groups of equal numbers were obtained: 33 High versus 33 Low scorers.

Responses on catch trials were only extremely rare (2.2% of catch trials), and no participants had to be excluded from analysis on this basis. For each participant, trials with RTs less than 150 ms or in excess of 1000 ms were regarded as errors and not analysed (less than 1% of trials).

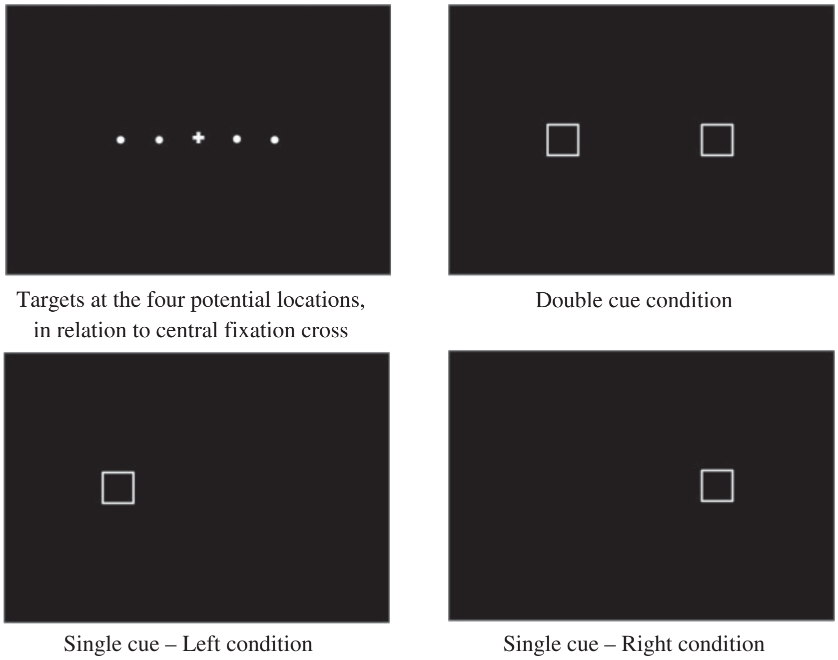

Figure 2. Sample stimuli in the present experiment.

Main analyses

A three-way, repeated-measures analysis of variance (ANOVA) was performed with the variables cue type (left, right or double) and target location (10° left, 5° left, 5° right or 10° right) as within-subject variables, and MMI (high or low) as a between-subject variable. Mean RTs are tabulated in Table 2.

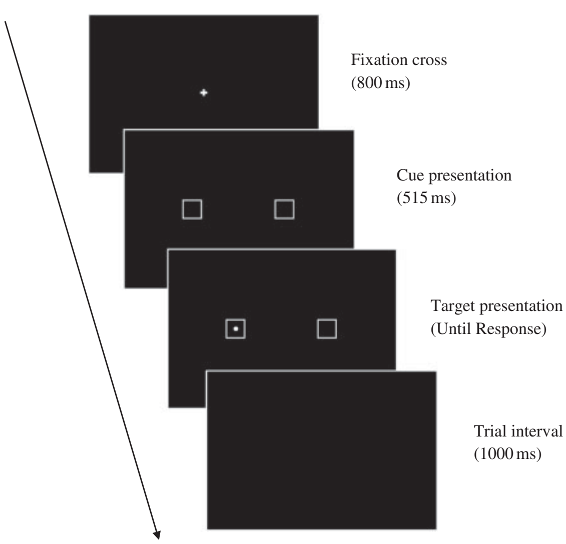

Figure 3. Schematic of the sequence of trial events in the present experiment. The task was to respond upon detection of the target (white dot).

The three-way (cue type × target location × MMI) interaction was significant, $F\ (6, 384) = 2.46$, $p < .05$, $\eta_p^2 = .21$, and appears in Figure 4.

Post-hoc tests revealed that for the single cue condition, the effect of trial type was significant regardless of the level of MMI. For both High- and Low-MMI participants: RTs on valid trials (Low: 300 ms, High: 306 ms) were significantly faster than those on valid probe trials (342 ms, 359 ms), $t(32) = 11.05$, $p < .001$ and $t(32) = 14.33$, $p < .001$, respectively (see Figure 5).

For the double cue condition, the effect of trial type was nonsignificant for Low MMI participants: RTs on valid and valid probe trials were comparable (306 ms vs 308 ms), $t(32) = .91$, $p = .37$. In contrast, the effect of trial type was significant for High-MMI participants: RTs on valid trials were faster than on valid probe trials (316 ms vs 330 ms), $t(32) = 4.84$, $p < .001$ respectively (see Figure 6).

Summarising the earlier results in conjunction with the present hypotheses:

(1) The first hypothesis was supported: for the single cue conditions, all participants, regardless of MMI, demonstrated faster RTs for targets that appeared in cued locations, over those which appeared in irrelevant locations.
(2) The second hypothesis was supported for the double cue condition, participants with Low-MMI scores had comparable RTs for

TABLE 2
Mean response times in milliseconds (ms) for respective conditions in the present experiment

		Target location			
MMI	*Cue type*	*10° left*	*5° left*	*5° right*	*10° right*
Low	Left	303 (6.22)	336 (7.76)	351 (8.06)	366 (7.29)
	Right	372 (8.65)	355 (7.23)	348 (7.66)	297 (6.22)
	Double	306 (5.76)	306 (6.41)	310 (6.55)	307 (6.31)
High	Left	307 (4.71)	358 (5.98)	358 (6.23)	380 (7.77)
	Right	397 (7.77)	380 (6.60)	361 (6.40)	304 (4.40)
	Double	319 (5.60)	328 (6.58)	332 (8.20)	313 (5.17)

Standard errors are reported in parentheses.

targets appearing in cued and irrelevant locations.

(3) Finally, the third and critical hypothesis was supported: for the double cue condition, participants with High MMI had faster RTs for targets in cued locations, compared to those in irrelevant locations.

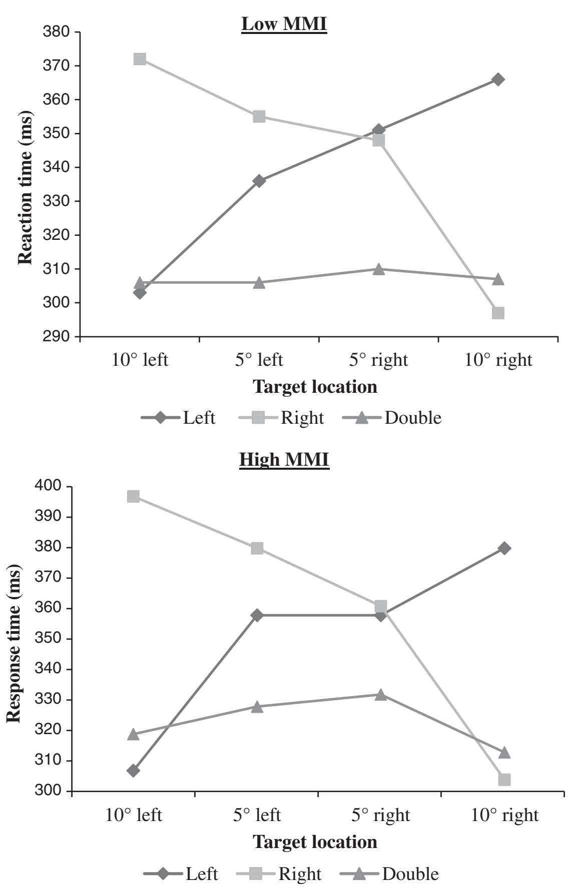

Figure 4. Response time trends in milliseconds (ms) for Low- and High-MMI participants.

DISCUSSION

The present experiment replicated one of the central findings in McCormick et al. (1998): RTs increased as targets are presented further from cued locations in the single cue conditions. This RT gradient has also been observed in prior studies, which used probes to test the spatial extent of visual attention (LaBerge, 1983; Shulman, Wilson, & Sheehy, 1985). Two interpretations have been offered to explain this gradient. Umiltà, Riggio, Dascola, and Rizzolatti (1991) proposed that increasing RTs could reflect the need to shift attentional focus, whereas McCormick and Klein (1990) suggested that the gradient could reflect diminishing concentrations of attentional resources at distances further from the cued location.

McCormick et al. (1998) did not observe such a gradient in their double cue condition. Accordingly, it was concluded that either participants had no need to shift attention to targets, which appeared in irrelevant locations, or similar levels

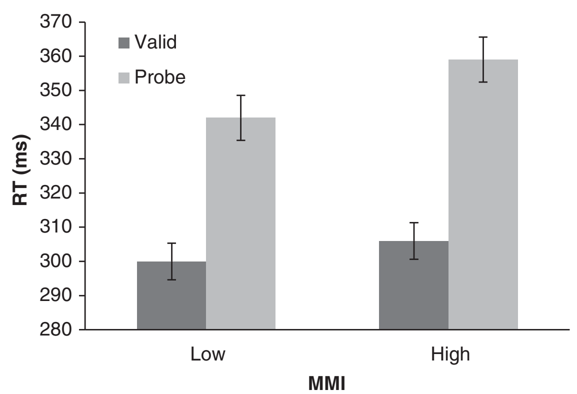

Figure 5. Single cue condition: effect of trial type at each level of MMI. Error bars indicate standard errors.

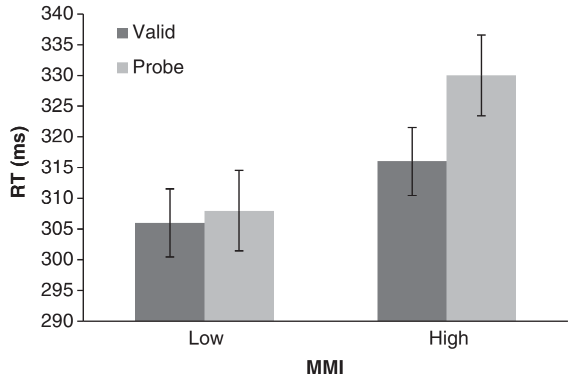

Figure 6. Double cue condition: effect of trial type at each level of MMI. Error bars indicate standard errors.

of attention had been deployed across all four potential target locations. Both interpretations are consistent with the idea of a single attentional focus expanded to encompass noncontiguous cued locations, as predicted by the zoom lens model.

As hypothesised, and consistent with McCormick et al. (1998) findings, no RT gradient was observed in the double cue condition for participants with Low MMI scores. RTs to targets appearing at cued and irrelevant locations were comparable. This suggests that a unitary mode of attention was being employed by these participants.

In contrast, the critical finding in the present experiment was the observation of an RT gradient in the double cue condition for participants with High MMI scores. RTs to targets at cued locations were faster than for those at irrelevant locations. As highlighted earlier, this suggests that (1) High-MMI participants had to shift attention from cued locations to attend to targets in the irrelevant region in between, or (2) High-MMI participants had deployed higher concentrations of attention at cued locations, compared to irrelevant locations. Both interpretations are consistent with the idea of the deployment of two attentional foci in noncontiguous locations (i.e., a demonstration of split attention)[2].

Taking these results together, an interpretation based on MMI variability seems to provide excellent insights into the conditions under which split attention tends to occur. MMI is a measure of media multitasking behaviour. The 'score' obtained is an estimation of the number of media forms a participant tends to concurrently use in a typical hour of media consumption. Thus, the critical difference between Low- and High-MMI participants is the behavioural tendency to consume multiple visual media forms simultaneously. Our results suggest that individuals who tend to consume multiple visual media forms simultaneously, as indicated by High MMI scores, employed a split mode of attention when presented with cued noncontiguous locations, whereas those who tend to consume fewer visual media forms simultaneously, as indicated by Low MMI scores, employed a unitary mode of attention when presented with these same locations.

This suggests a relationship between simultaneous media usage and the capacity to split attention. If, as we have proposed, ecological differences in terms of the media-saturation of participants' environments account for the contradictory results between the present findings and those of McCormick et al. (1998), we suggest that the tendency to split attention ought to follow prolonged simultaneous media usage, and not vice versa (although this remains an open empirical question at this juncture, as MMI scores could not be experimentally manipulated to provide a fuller claim).

How, then, might such a tendency develop? It has been suggested that maintaining a split mode of attention is inherently more effortful than unitary attention, and leads to performance costs (Bichot et al., 1999; Cave et al., 2010). We propose that the employment of a split or unitary mode of attention could be a strategic decision made by the visual system, depending on whichever constituted the least effortful means of extracting information from a visual representation. Prolonged simultaneous media usage could act as a form of practice that reduces the effort needed to maintain split attention. This, in turn, increases the occasions where split attention becomes strategically optimal, and thus employed in lieu of unitary attention. A new direction for future investigations would be to empirically test this hypothesis through the use of training studies.

General implications and future work

The present experiment revealed a significant correlation between participants' media multitasking

[2] The smaller magnitude of the cuing advantage (Valid Probe trial RTs – Valid trial RTs) for High MMI participants in the double cue condition (16 ms) compared to the single cue condition (53 ms) suggests that the attentional foci, when attention is split, have much lower concentrations of attentional resources compared to when only one region of attentional focus is deployed. While interesting and noteworthy, a detailed examination of the mechanisms of split attention is beyond the scope and intent of the present work.

behaviours and their tendency to employ a split mode of attention. With respect to the extant split attention literature, the present study contributes to converging evidence, which suggests that the concurrent deployment of multiple attentional foci is possible. Furthermore, the present data advanced our understanding of the conditions under which focal attention might split. Specifically, they implicate the possibility of individual differences in the capacity, or at least a tendency, to split attention. Potential individual differences, which need not necessarily stem from media multitasking behaviour alone, might at least in part explain the body of conflicting results pointing to unitary attention. Prior attempts to reconcile conflicting findings have typically focused on paradigm differences (Dubois et al. 2009; Kramer & Hahn, 1995). A full(er) picture may only be achieved by considering the interaction between individual and paradigm factors.

In addition, the present study contributes to the general finding that ecological experiences influence various visual attentional processes. An interesting direction for future research would be to explore the possibility of other ecological influences on the capacity to split attention. One possible candidate is habitual video game playing. Expert gamers are significantly better at identifying targets presented towards the periphery of their vision than nogamers, which has been interpreted as superior ability at distributing attentional resources throughout the visual field (Green & Bavelier, 2003). Given that split attention can be conceptualised as the ability to deploy attention in a flexible manner, the attention distribution benefits stemming from habitual game playing might have an impact on the capacity to split attention as well. Currently, the MMI contains an item relating to video game hours per week. It would be interesting for future studies to investigate whether this measure might associate with attention splitting and, by extension, for particular genres of video games. It would also be useful for future studies to eventually be able to infer directions of causality. To reach this goal, these future investigations can take on the form of a training study or adopt the tracking of performances over time on a longitudinal basis, which would have strengthened the case that ecological differences have an impact on an individual's capacity to demonstrate splitting attention.

CONCLUSION

We report novel evidence that ecological differences, arising from our increasingly media-saturated environment and how we choose to interact with it, could lead to individual differences in the capacity to demonstrate split focal attention. This advances our understanding of the exact conditions under which focal attention might split, and might partly account for the conflicting evidence for and against split attention found in the literature. Further studies may consider other potential sources of individual differences that govern the tendency to split visual attention. We are hopeful that such ecological factors as media multitasking will continue to shed new light on the persistent puzzle of just when and why splitting visual focal attention occurs.

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