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Splitting Visual Focal Attention? It Probably Depends on Who You Are

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Abstract

Research evidence now suggests that the deployment of multiple attentional foci in non-contiguous 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. The present study is the first in the literature to examine the possibility that ecological differences arising from our increasingly media-saturated environment may result in individual differences in the capacity to demonstrate splitting focal attention. Results suggest a significant relationship between the behavioural preference for consuming multiple media forms simultaneously and the capacity to employ a split mode of attention.

Keywords: Ecological differences; splitting focal attention; media multitasking

Introduction

In visual attention research, whether the focus of attention can be divided is an issue of debate. Several authors espouse the view that the focus of attention is unitary and indivisible in nature (e.g. Eriksen & Yeh, 1985; McCormick & Klein, 1990; Pan & Eriksen, 1993). In order to account for the processing of multiple visual stimuli in different spatial locations, two different theories have been proposed. The *serial shifting theory of attention* suggests that the focus of attention rapidly shifts between different locations (Eriksen & Eriksen, 1974; Posner, 1980), whereas the *zoom lens theory of attention* suggests that the focus of attention is adjusted in size to accommodate multiple locations (Eriksen & St. James, 1986).

However, there is a growing body of evidence which supports the possibility of split attentional foci, or allocation of attention to noncontiguous regions (for review, see Jans, Peters, & De Weerd, 2010; *cf.* Cave, Bush & Taylor, 2010). For instance, Awh and Pashler (2000) presented participants with a 5 x 5 stimulus array and tasked them with identifying two targets following the onset of cues (validity = 80%). Results showed a strong accuracy advantage at cued locations that did not apply to targets appearing between cued locations, which suggest a divided focus of attention. In their appraisal of the current literature, Cave, Bush and Taylor (2010) concluded "the weight of evidence suggests that some form of split attention is possible in some circumstances".

With the focus on establishing the possibility of split attention, there has been little research into the exact circumstances under which split attention might arise. This was the crux of a recent study by Lim and Lee (2011), who hypothesized that adoption of a unitary or split mode of attention could be a strategic choice made by the visual system, depending on whichever was the least effortful means of extracting target information from a particular visual presentation. To test this, Lim and Lee employed a modified version of the paradigm used in McCormick, Klein and Johnston (1998).

In the double cue condition of the original study, boxes 10° to the left and right of a central fixation point were 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. Results showed that reaction times (RTs) for targets in cued locations (i.e. in boxes) did not differ from those that appeared in irrelevant locations (i.e. outside boxes), which was interpreted as indicative of a unitary mode of attention (See Figure 1).

For their modified version of the double cue condition, Lim and Lee introduced a vertical wall positioned in the centre of the visual display with the intent of preventing a single locus of attention from encompassing both boxes. It was believed that this would incentivize a split mode of attention and, in contrast with McCormick et al. (1998), give rise to RTs for targets in irrelevant locations that were

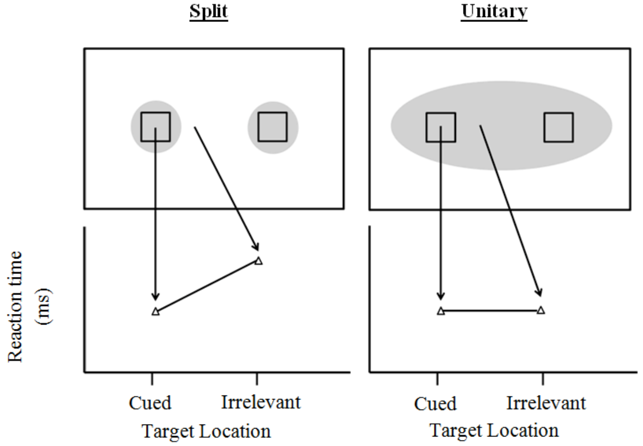


Figure 1. *Predicted result trends, depending on mode of attention employed in double cue condition (McCormick et al., 1998).*

slower than those in cued locations. Most intriguingly, while results revealed the expected trend, this was regardless of the presence or absence of the vertical wall. In other words, participants showed the capacity to split attention for both the experimental and control conditions – a contradiction of McCormick and colleagues' findings.

To explain this contradiction, Lim and Lee point towards the 10-odd years that have passed between the two studies. While this may not seem much in absolute terms, the 21st century has seen an exponential increase in the prevalence of digital devices in modern society. Compared to the undergraduates of 1998, those in 2011 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, Nass & Wagner, 2009). Studies have shown cultural differences in attentional phenomena such as change blindness (Masuda & Nisbett, 2006), while learned visual experiences have been known to result in differential allocations of visual attention (Chun, 2000). In a similar vein, by demanding the allocation of attention to multiple objects, today's media-saturated environment may encourage the development of the capacity to split attention.

In our present study, we examine the suggested relationship between media usage and splitting attention. To this end, we borrow the Media Multitasking Index (MMI) developed by Ophir et al. (2009), a measure of simultaneous media usage. High and Low media multitaskers, as indicated by the MMI, have been found to demonstrate fundamental differences in cognitive control as well as information processing approaches. We believe that similar differences may be observed in the capacity to split attention as well. Furthermore, to strengthen the case that the contradiction between Lim and Lee (2010) and McCormick et al. (1998) stems from ecological, rather than paradigm, differences, we employed a close replication of McCormick's paradigm.

It is hypothesized that:

1. MMI should not result in between subject performance differences for 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 behavioral experiment.

Participants.

66 introductory psychology students participated for course credit.

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 and colleagues (2009) had included items about non-visual media forms, such as music, in their original study. Given that the present study is primarily interested in the deployment of visual attention, all such irrelevant items 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 phonecalls.

The questionnaire addressed 10 different media forms: printed media, television, computer-based video (e.g. YouTube), video or computer games, non-call related mobile phone usage, online instant messaging, text messaging, e-mail, 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 x 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

We recoded matrix responses as follows: 1 "Never" = 0, 2 = 0.33, 3 = 0.67, 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 for each 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 summarized with the following formula:

$$MMI = \sum_{i=1}^{9} \frac{m_i \times h_i}{h_{total}}$$

where m_i is the number of media typically used while using 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.

Stimuli

As far as possible, the stimuli, design, and procedure of our experiment were kept in accordance with Experiment 1 of McCormick et al. (1998). While our participants completed fewer trials, the proportion of trials for each condition remained the same (see Table 1).

The visual display comprised of a black background and centered white fixation cross (0.4° by 0.4°). 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 positioned at one of four possible locations on the horizontal median (10° left, 5° left, 5° right, or 10° right).

Design

The experiment used a 3x4 fully within factorial design. The two independent variables were (1) type of cue: (a) single box to the left, (b) single box to the right, and (c) double box, and (2) location of target dot: (a) 10° left, (b) 5° left, (c) 5° right and (d) 10° right.

Procedure

The sequence of events (see Figure 2 for schematic) for each trial was as follows: the fixation cross was presented for 800ms. This was followed by a single or double-box cue. After a 515ms interval, the target dot 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).

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 420 trials. Four rest periods were interspersed during this session. The total number of trials for each cue-target combination is presented in Table 1.

Table 1
Number of trials for each Cue-Target combination.

	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

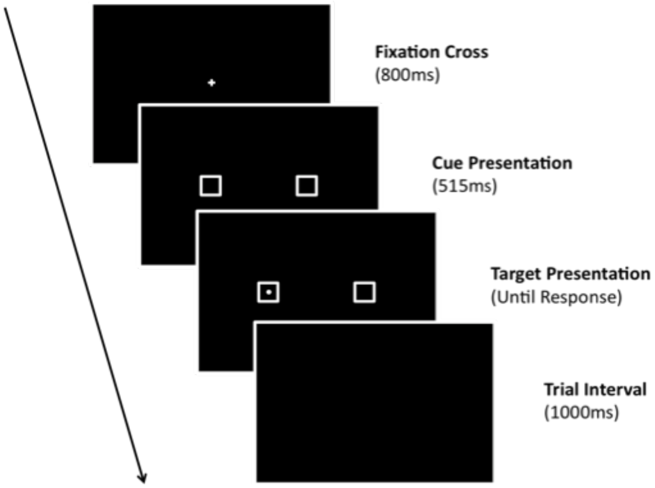


Figure 2. *Schematic of the sequence of a trial.*

Results

Participant MMI scores ranged from 0.29 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 further 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 150ms or in excess of 1000ms were regarded as errors and not analyzed (less than 1% of trials).

A repeated measures analysis of variance (ANOVA) was performed that included 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. Relevant means have been summarized in Table 2.

The Mauchly's test of sphericity was significant, $p < .05$, for the cue type x target location interaction term, suggesting that sphericity was violated. Accordingly, a more stringent F-test (Greenhouse-Geisser) was used. Results revealed a significant main effect for cue type, $F(2, 128) = 235.84$, $p < .001$, $\eta_p^2 = .90$. There was also a significant main effect for target location, $F(3, 192) = 34.44$, $p <.001$, $\eta_p^2 = .59$. The main effect for MMI did not reach significance, $F(1, 64) = 3.19$, $p = .08$. In terms of interactions, the cue type x MMI interaction was non-significant, $F(2, 128) = 0.99$, $p = .37$. Both the cue type x target location and target location x MMI interactions were significant, $F(6, 384) = 189.49$, $p < .001$, $\eta_p^2 = .90$ and $F(3, 192) = 4.66$, $p < .01$, $\eta_p^2 = .16$ respectively.

Most important, all effects were qualified by a significant cue type x target location x MMI interaction, $F(6, 384) = 2.46$, $p < .05$, $\eta_p^2 = .21$. Post-hoc tests revealed that the

Table 2
Mean RTs (in ms)

		Target Location			
MMI Score	Cue Type	10° Left	5° Left	5° Right	10° Right
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)
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)

Note: Standard errors are in parentheses.

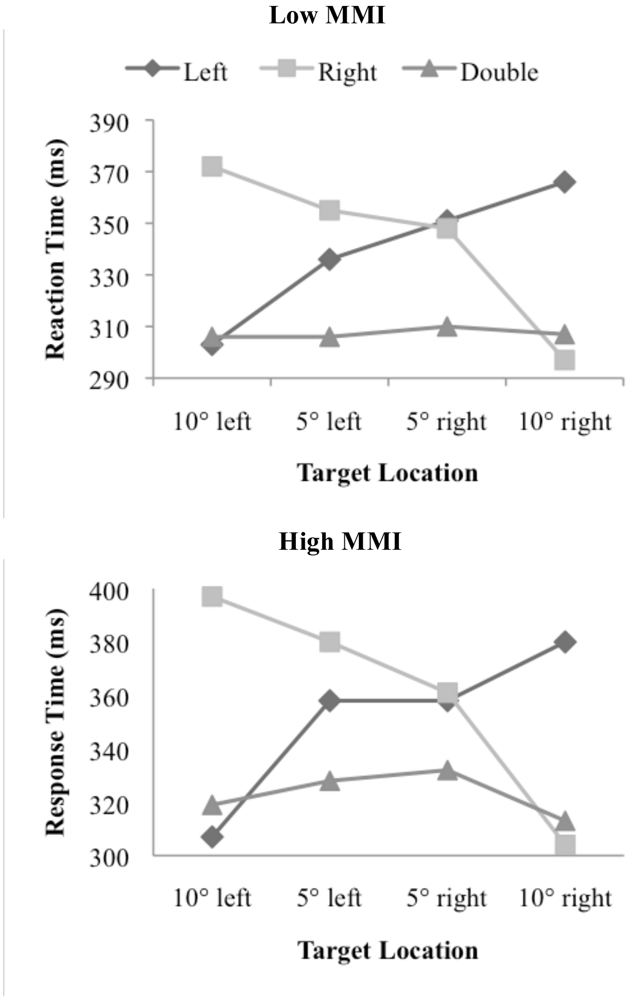
target location x MMI interaction was non-significant for the left cue condition, *F*(3, 192) = 2.36, *p* = .084, but significant for the right and double cue conditions, *F*(3, 192) = 3.40, $p < .05$, $\eta_{p}^{2} = .05$ and *F*(3, 192) = 4.24, *p* = .01, $\eta_{p}^{2} = .22$ respectively. The significant target location x MMI interaction was examined individually for the right and double cue conditions. To test my hypothesis directly, we examined the simple main effect of target location at each level of MMI. For the right cue condition, the simple main effect of target location was significant for both High and Low MMI participants, *F*(3, 96) = 87.68, $p < .001$, $\eta_{p}^{2} = .90$ and F(3, 96) = 134.16, $p < .001$, $\eta_{p}^{2} = .81$ respectively. For the double cue condition, the simple main effect of target location was non-significant for Low MMI participants, *F*(3, 96) = 1.07, *p* = .36; but significant for High MMI participants, *F*(3, 96) = 7.39, $p < .001$, $\eta_{p}^{2} = .19$.

This 3-way interaction is reflected in Figure 3. A distinct RT gradient can be observed for both single cue conditions, regardless of the MMI scores of participants: RT was fastest at the cued location, and became slowed as the target was presented further from the cue. For the double cue condition, relatively constant RTs can be observed at each target location for Low MMI participants. For High MMI participants, a slight RT gradient can be observed between cued and irrelevant locations, with RTs being faster at cued locations.

As a further investigation of the 3-way interaction, and as a planned comparison, we collapsed both single cue conditions into one condition, and sorted the RT data by *trial type*. Specifically, we analysed the RT difference between *valid* trials, where the target appeared at cued locations, and *valid probe* trials, where the target appeared 5° to the left or right of cued locations. The outcomes are as follows:

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: 300ms, High: 306ms) were significantly faster than those on valid probe trials (342ms, 359ms), *t*(32) = 11.05, $p < .001$ and *t*(32) = 14.33, $p < .001$ respectively (See Figure 4).

For the double cue condition, the effect of trial type was non-significant for Low MMI participants: RTs on valid and valid probe trials were comparable (306ms vs 308ms), *t*(32) = 0.91, *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 (316ms vs 330ms), *t*(32) = 4.84, $p < .001$ respectively (See Figure 5).


Low MMI

High MMI

Figure 3. *Response time trends (in ms) for Low and High MMI participants.*

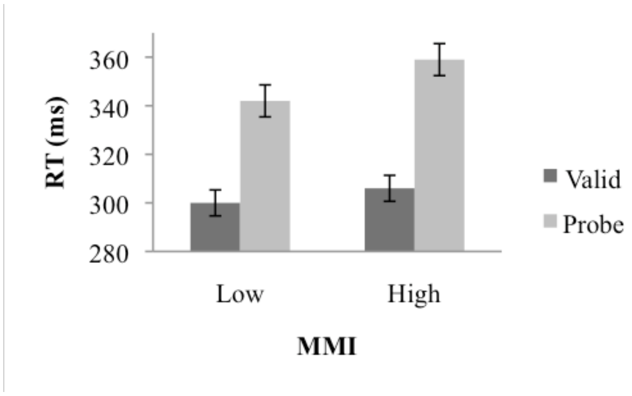


Figure 4. *Single cue condition: Effect of trial type at each level of MMI. Error bars indicate standard error.*

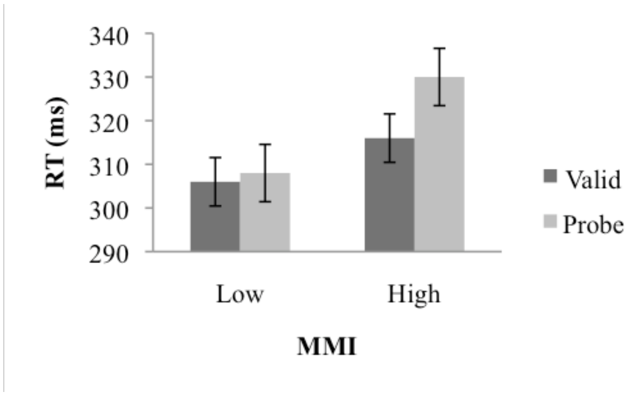


Figure 5. *Double cue condition: Effect of trial type at each level of MMI. Error bars indicate standard error.*

Discussion

The present experiment has replicated one of the central findings in McCormick et al. (1998): Increasing RTs 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 (e.g. LaBerge, 1983). 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, while 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 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.

Consistent with McCormick and colleagues' (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 elaborated above, 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 – a demonstration of split attention.

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, which we elaborate below.

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 have established the following:

1. People 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.
2. People who tend to consume fewer visual media forms simultaneously, as indicated by Low MMI scores, employed a unitary mode of attention when presented with the same.

This suggests a relationship between simultaneous media usage and the capacity to split attention. If, as argued by Lim and Lee (2011), ecological differences in terms of the media-saturation of participants' environments account for the contradictory results between Lim and Lee (2011) and McCormick et al. (1998), this further suggests that the capacity to split attention ought to follow prolonged simultaneous media usage, and not vice versa (however, 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 development take place? As suggested in Lim and Lee (2011), the employment of a split or unitary mode of attention could be a strategic decision made by the visual system, depending on whichever was the least effortful means of extracting information from a visual representation. It has also been suggested that maintaining a split mode of attention is inherently more effortful than unitary attention, and leads to performance costs (Cave et al., 2010). Pulling these trains of thought together, we propose that prolonged simultaneous media usage acts as a form of practice which 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.

With respect to existing split attention literature, the present study contributes to converging evidence which suggests that the deployment of multiple attentional foci is possible. Furthermore, the present study advances our understanding of the conditions under which focal attention might split. New evidence is presented, for the first time in the literature, supporting 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 behavior 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 picture may only be achieved by considering the interaction between individual and paradigm factors.

In addition, we wish to highlight that the present study contributes to the general finding that ecological experiences influence various visual attentional processes. An interesting direction of 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 non-gamers, which has been interpreted as superior ability at distributing attentional resources throughout the visual field (Green & Bavelier, 2003). Given that split attention can be conceptualized 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. This possibility is both a theoretically as well as an empirically exciting one.

In 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 in the capacity to split attention. Moving forward, we are very hopeful that ecological factors will continue to shed new light on the persistent puzzle of splitting visual focal attention.

References

Castiello, U., & Umiltà, C. (1992). Splitting focal attention. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 837-848.

Cave, K. R., Bush, W. S., & Taylor, T. G. G. (2010). Split attention as part of a flexible attention system for complex scenes: Comments on Jans, Peters, and De Weerd (2010). *Psychological Review, 117,* 685-696.

Chun, M. M. (2000). Contextual cueing of visual attention. *Trends in Cognitive Sciences, 4,* 170-178.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16,* 143-149.

Eriksen, C.W., & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom-lens model. *Perception & Psychophysics, 40,* 225-240.

Eriksen, C. W., & Yeh, Y. Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance, 11,* 583-597.

Jans, B., Peters, J. C., & De Weerd, P. (2010). Visual spatial attention to multiple locations at once: The jury is still out. *Psychological Review, 117,* 637-684.

LaBerge, D. (1983). Spatial extent of attention to letters and words. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 371-379.

Lim, S. W. H., & Lee, L. N. (2011). When (and why) might visual focal attention split? In B. Kokinov, A. Karmiloff-Smith, & N. J. Nersessian (Eds.), *European perspectives on cognitive science.* New Bulgarian University Press.

Masuda, T., & Nisbett, R. E. (2006). Culture and change blindness. *Cognitive Science, 30,* 381-399.

McCormick, P. A., & Klein, R. (1990). The spatial distribution of attention during covert visual orienting. *Acta Psychologica, 75,* 225-242.

McCormick, P. A., Klein, R., & Johnston, S. (1998). Splitting versus sharing focal attention: Comment on Castiello and Umiltà (1992). *Journal of Experimental Psychology: Human Perception and Performance, 24,* 350-357.

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences, 106,* 15583-15587.

Pan, K., & Eriksen, C. W. (1993) Attentional distribution in the visual field during same-different judgments as assessed by response competition. *Perception & Psychophysics, 53,* 134-144.

Posner, M. I. (1980) Orienting of attention. *Quarterly Journal of Experimental Psychology, 32,* 3-25.

Umiltà, C., Riggio, L., Dascola, I., & Rizzolatti, G. (1991). Differential effects of peripheral cues on the reorienting of spatial attention. *European Journal of Cognitive Psychology, 3,* 247-267.